FACILITY FORM 602

N66 35177

(ACCESSION NUMBER) (THRU)

281

(PAGES) (CODE)

CR-77511

(NASA CR OR TMX OR AD NUMBER)

17

(CATEGORY)

DEVELOPMENT OF WELDING TECHNIQUES AND FILLER METALS FOR HIGH STRENGTH ALUMINUM ALLOYS

GPO PRICE $ ____

CFSTI PRICE(S) $ ____

Hard copy (HC) $6.00

Microfiche (MF) 1.50

ff 653 July 65

FINAL REPORT

to

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

Attn: PR-EC

Contract No. NAS8-1529
Control No. TP2-85364

Contract No. NAS8-20160
Control No. DCN 1-5-54-01221-01 (IF)

May 27, 1966

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

SOUTHWEST RESEARCH INSTITUTE
8500 Culebra Road, San Antonio, Texas 78206

DEVELOPMENT OF WELDING TECHNIQUES AND FILLER METALS FOR HIGH STRENGTH ALUMINUM ALLOYS

FINAL REPORT
Project No. 07-1063
Project No. 07-1757

by

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E. B. Norris

for

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama
Attn: PR-EC

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FOREWORD

This report was prepared by Southwest Research Institute under Contracts NAS8-1529 and NAS8-20160, "Development of Welding Techniques and Filler Metals for High Strength Aluminum Alloys," for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Propulsion and Vehicle Engineering Laboratory, Materials Division of the George C. Marshall Space Flight Center with Mr. Richard A. Davis acting as project manager.

ABSTRACT

A program was conducted to investigate possible means of improving the strength of welded aluminum alloys and to better define the mechanical and metallurgical characteristics of such weldments. The program extended over a period of five years and included the following areas of investigation:

(1) Development of welding techniques and filler metal alloys

(2) Evaluation of the uniaxial and biaxial mechanical properties of aluminum alloy weldments.

In the portion of the program directed toward the development of welding techniques, MIG and TIG weldments of the following materials were studied:

0.090-inch 2014, 2024, and X2020 aluminum alloy

0.75-inch 2219 aluminum alloy

0.090-inch, 0.187-inch, 0.50-inch, and 1.00-inch X7106 aluminum alloy

It was established that joint preparation methods (machining, cleaning, etc.) exert a strong influence on the soundness of welds for all material-process combinations included in the study. The variables associated with clamping fixtures were found to be the major factor in the control of the size of the zone of heat-affected base metal in the 0.090-inch 2014, 2024, and X2020 weldments. In general, the TIG process produced the most desirable weld bead configuration for all weldment types investigated. In addition, the TIG weldments were in general less susceptible to porosity than were the MIG weldments.

Techniques were developed for welding 0.75-inch 2219-T87 plate by the MIG process. The use of cold-wire feed was shown to reduce sagging of welds made with the torch in the horizontal position. The addition of copper to the molten weld puddle, by means of cold-wire feed, was also studied. Such copper additions resulted in an increase in the hardness of bead-on-plate weld deposits. The use of this technique for the fabrication of weldments resulted in incomplete solution of the added copper and the weldments exhibited lower strength than those made with commercial filler wire.

Bead-on-plate welds were made with several binary aluminum filler alloys (Cu, Ag, Mn and Si) and with one experimental multicomponent aluminum alloy. The results of this investigation indicated that the properties of the experimental alloys were no better than those of the commercial filler alloys.

A study of the microstructure of 0.75-inch TIG 2219-T87 weldments was conducted. Considerable quantities of $CuAl_2$ were observed in the grain boundaries of the weld deposits and in the adjacent heat-affected base metal and a needle-like precipitate tentatively identified as β (Al-Cu-Fe) was frequently formed in the toes of the welds. Metallographic and fractographic analysis of failed tensile specimens established that intermetallic precipitates play a significant role in the initiation of fracture.

The natural aging characteristics of X7106-T63 weldments, made with X5180, 5356, and 5556 filler wire were investigated. Marked increases in the uniaxial tensile strength of the weldments were observed to occur for aging of periods up to eight weeks. In some cases, the strength of the weld deposit increased to a value such that the location of the fractures in tensile test specimens shifted from the weld deposit to the heat-affected base metal.

Crack susceptibility tests were conducted on 0.125-inch 2219-T87, 2014-T6, and X7106-T63 sheet material. These tests established that, for this thickness, the susceptibility of X7106-T63 to hot cracking during welding is comparable to that of 2014-T6. The 2219-T87 material exhibited a degree of crack susceptibility considerably lower than that of the other two alloys.

In the evaluation of the mechanical properties of aluminum alloy weldments detailed studies were conducted in the following categories:

(1) Uniaxial tensile properties of 0.75-inch TIG 2219-T87 weldments

(2) Uniaxial and biaxial properties of 0.125-inch MIG and TIG weldments of 2014-T6, 2219-T87, and X7106-T63 alloys.

Methods of measurement of the yield strength of 0.75-inch TIG 2219-T87 weldments were studied. It was established that the plastic deformation of tensile specimens was essentially confined to the weld deposit and heat-affected base metal. Measurements of elongation at fracture within the weld deposit resulted in values in the order of 20 percent for specimens exhibiting an overall elongation of approximately 6 percent. It was also determined that the yield strength of the weld metal is exceeded at stress levels well below that corresponding to a strain of 0.2 percent in a 2-inch gage length.

Uniaxial tensile tests, hydraulic bulge tests, cylinder burst tests, MIT biaxial tests and LTV biaxial tests were performed on 0.125-inch 2014-T6, 2219-T87, and X7106-T63 parent metal and weldments. The results of this study established that the hydraulic bulge test may be used for the determination of the 1:1 biaxial mechanical properties of aluminum alloy weldments. It was also shown that the biaxial mechanical properties of such weldments are essentially equivalent to the uniaxial properties. This observation indicates that uniaxial test data are adequate for use in designing high-strength aluminum alloy weldments.

Among the 2014-T6 weldments tested, those fabricated by the MIG process using 4043 filler wire consistently exhibited the lowest mechanical properties. In the case of the 2219-T87 alloy, the MIG and TIG weldments were found to have approximately equal properties. The TIG X7106-T63 weldments exhibited the highest uniaxial and biaxial strength of all of those tested.

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I. INTRODUCTION

The decision to use high-strength aluminum-copper alloys for the construction of the tankage required for the SATURN vehicle was based primarily on their favorable strength-to-weight ratio and their inherent freedom from embrittlement at the low temperatures encountered in the storage of liquid hydrogen. It was recognized by NASA that the performance of fabricated structures of the candidate alloys, 2014-T6 and 2219-T87, is limited by the mechanical properties of the welded joint. It was thus apparent that investigation of the variables affecting the mechanical properties of welded joints was necessary to improve the reliability of the SATURN vehicle.

In February 1961, Contract NAS8-1529 was issued by the Marshall Space Flight Center of the National Aeronautics and Space Administration to initiate a program to investigate possible means of improving the strength of welded aluminum-copper alloys and to better define the mechanical and metallurgical characteristics of such weldments for this critical application. This basic contract was amended through a series of change notices until it was terminated in June 1965. The change notices and their effective dates were as follows:

NAS8-1529, Mod 1 - 7 February 1961 to 27 March 1962
NAS8-1529, Mod 2, Mod 3, and Mod 4 - 27 March 1962 to 27 April 1963
NAS8-1529, Mod 5 - 27 April 1963 to 26 June 1964
NAS8-1529, Mod 6 - 27 June 1964 to 29 June 1965

At this point, a new contract, NAS8-20160, was issued to continue the investigation of the strength of welded joints in aluminum-copper alloys subjected to multiaxial loading conditions. In addition, the new contract provided for investigation of some of the characteristics of weldments of alloy X7106 (aluminum-zinc-magnesium) which develops higher strengths through natural aging processes.

By natural evolution and redirection, the program emphasis was changed from one year to the next, keyed to meet the urgent NASA program requirements. Early attempts to provide higher weld strength by control of weld chemistry were ineffective, and, as the hardware programs were defined, it was considered necessary to provide a better understanding of the performance of welded structure. The later phases of the program were therefore directed toward establishing the strength and failure characteristics of weldments which exhibited an ultimate strength lower than the yield strength of the parent metal.

In the course of the five-year period, annual summary reports were submitted at the conclusion of each portion of the program. Since Contract NAS8-20160 was, in effect, a continuation of NAS8-1529, it was desirable that the results of the two contracts be included in a single report covering the entire program. This report, therefore, summarizes the investigations carried out during the period from February 1961 to February 1966 and is organized to present a review of the most important conclusions from the work performed indicating the basis for the evolution of the program. In addition, the details of the work carried out under Contract NAS8-20160 are included in this report as appendices, constituting an annual summary report for that contract.

II. PROGRAM SUMMARY

A. Contract NAS8-1529, Mod 1 (7 February 1961 to 27 March 1962)

The scope of work set forth in Contract NAS8-1529 provided for investigations related to the following major topics:

(1) The development of welding techniques for high-strength aluminum alloys.

In this phase of the program, emphasis was to be placed on alloys 2014, 2024, and X2020 as specified by the technical supervisor of the contract. The scope of work included investigations of methods of fusion welding of the alloys, the determination of the mechanical properties of the welded joints, and metallurgical examination and analysis of the weldments. An investigation of the use of applicable, commercially available filler materials and specially prepared filler metal alloys was also included in the scope of work. Both the automatic tungsten-inert-gas technique (TIG)* and the automatic metal-inert-gas technique (MIG)* were to be employed in this phase of the program.

(2) Assessment of the role of diffusion of elements from the molten weld puddle into the base metal.

(3) The development of manual repair welding techniques for the alloys included in the program.

In the course of the work carried out under this contract, techniques for welding 0.090-inch 2014, 2024, and X2020 high-strength aluminum alloys using commercial filler wire alloys were developed. The influence of travel speed, wire feed, backup groove design and the spacing of the positioner fingers on the weld contour, penetration and the size of the heat affected zone were investigated. Among the above variables, the spacing of the positioner fingers exhibited the strongest influence on the width of the heat affected zone. It was also found that special precautions in joint preparation and environmental control were necessary to reduce porosity in the welds.

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*These welding processes are also referred to as the gas-tungsten-arc (GTA) and the gas-metal-arc (GMA) processes.

The age hardening characteristics of 2014, 2024, and X2020 parent metal alloys and 2014-T6 TIG and MIG weld deposits were also established. The results of this study indicate that no significant increase in the mechanical properties of weldments of these alloys occur as the result of natural aging.

A number of techniques were employed to detect the extent of the diffusion of elements within the weld zone. No indications of any significant degree of diffusion of the alloying elements were observed.

The filler metal development and the weld repair study, included in the initial scope of work, were not accomplished because of the urgent need for additional data in the foregoing areas of investigation.

B. Contract NAS8-1529, Mod 2, Mod 3, and Mod 4 (27 March 1962 to 27 April 1963

The research program was continued for a second year under Modifications 2, 3, and 4 of Contract NAS8-1529. The scope of work for this phase of the program was established to accomplish the following objectives:

(1) The continuation of the development of welding techniques and filler metals to improve the as-welded joint efficiency of high-strength aluminum alloys.

Equipment procured and methods developed during the first year of the contract were to be employed in this phase. In this portion of the program, however, the major emphasis was to be placed upon the development of welding techniques for the plate thicknesses, i.e., 0.25 inch and up. The development of techniques for welding with the torch in the horizontal position, simulating production methods planned for future SATURN vehicles, was included in this portion of the program. Both the automatic TIG and the automatic MIG welding processes, employing either helium or argon, as appropriate, or a combination of the two, as the shielding gas, were to be utilized in the welding technique development study. The work in this portion of the program was to be directed toward optimizing the joint efficiency of the as-welded alloys. Postweld heat treatment was not included in this investigation; however, provision was made to establish the extent of strengthening which may be derived from natural aging of the weldments.

(2) Continuation of the efforts to assess the role of diffusion of elements from the molten weld puddle into the base metal.

(3) A development of manual repair welding techniques for the alloys included in the program.

Provision was made for the investigation of the feasibility of repairing defective welds without any postweld heat treatment and for the determination of the efficiency which may be expected from such repaired welds.

During this phase of the research program, techniques for welding 3/4-inch 2219-T87 aluminum alloy, utilizing the MIG process, were investigated. Both 60° and 90° double-V welded joints, made in the horizontal position, were evaluated. No significant differences in the mechanical properties of sound welds of either of the two joint configurations were noted. In this investigation, both joint geometry and joint preparation techniques, i.e., cleaning, etc., were found to be extremely important in the production of a sound weld. In addition, the results of the investigation indicated that the use of either helium or argon as a shielding gas had no significant influence on the strength of the weldments.

Sagging of the weld puddle, a problem encountered in the fabrication of horizontal welds, was observed to be reduced by the use of cold wire feed. The use of cold wire feed, however, resulted in a slight reduction in the strength of the joints. It was determined that the addition of cold wire to the weld puddle does not affect the age hardening characteristics of the weld bead.

The influence of the addition of copper tothe molten weld puddle, by means of cold wire feed, was also studied. The addition of copper in the range of 12 to 36 percent resulted in bead-on-plate weld deposits which were harder than the adjoining heat affected zones. Transverse cracks developed in the beads made with the 36-percent copper addition.

In the work directed toward the development of filler metal, bead-on-plate welds were made with specially prepared binary aluminum alloy filler wire. The influence of copper, silver, manganese, and silicon on the natural and artificial aging characteristics of such weld deposits were established. Based on the results of this work, an experimental 6.5 percent copper, 1.0 percent silicon, 1.0 percent silver, 0.5 percent manganese filler metal was prepared and used to fabricate 2219-T87 weldments. The mechanical properties of the weldment prepared with the experimental wire were slightly lower than those obtained with 2319 filler wire.

The investigation of repair welding techniques was rescheduled for inclusion in an extension of the program in order to provide for the need of additional data in the other phases of this portion of the investigation.

C. Contract NAS8-1529, Mod 5 (27 April 1963 to 26 June 1964)

Under Contract NAS8-1529, Mod 5, the research program was extended into the third year. The scope of work was expanded to provide for further investigations directed toward improving the as-welded joint efficiency of high-strength aluminum alloys. In this portion of the program, emphasis was placed on weldments in alloy 2219 made by the TIG process. Provision was made for four specific areas of investigation as follows:

(1) A study of the microstructural characteristics of the weld zone including both the cast structure and the adjacent zone of heat-affected base metal.

(2) A study of the failure mechanisms in aluminum alloy weldments under uniaxial and biaxial loading conditions.

This phase of the program provided for the evaluation of weldments in materials and thicknesses representative of production parts.

(3) An investigation of the possible methods of measuring the yield strength of welded joints.

(4) A study of the methods of measuring weld ductility.

This portion of the program provided for the development of a method of measuring the ductility of welded joints which would yield results suitable for correlation to base metal properties and which would provide data with a definite design significance.

In the investigation of the microstructure of the weld zone, it was observed that considerably more $CuAl_2$ formed in the grain boundaries of the weld deposit and the adjacent heat-affected base metal than is normally found in the parent metal. In addition to the characteristic microstructure, a needle-like precipitate was found to be associated with the region of the toes of the weld.

The study of the failure mechanisms established that the failures initiated at the toe of the weld in the region where the needle-like intermetallic precipitate was observed. Typically, the fracture propagated diagonally through the weld to the opposite toe. Electron fractographic analysis of the fractured surfaces indicated that the basic mechanism of failure was that of the nucleation, growth and coalescence of microvoids. The electron fractographs revealed that the amount and distribution of second-phase particles exerted a significant influence on the nucleation and growth of voids. In general, the same fracture characteristics were observed for the specimens subjected to biaxial loading conditions.

In the work directed toward the measurement of the yield strength and ductility of welded joints, it was found that the plastic deformation occurring in a uniaxial tensile test is essentially confined to the weld deposit and heat-affected base material. Measurements of elongation at fracture within the weld deposit resulted in values in the order of 20 percent for specimens in which a 5.9-percent elongation was determined from a 2-inch gage length. Of the total strain occurring prior to fracture, over half was shown to be associated with deformation of the weld deposit. The results of the measurements of yield strength and ductility of the weld metal illustrate that the yield strength of the weld deposit is exceeded at stress levels considerably below that corresponding to a 0.2-percent offset based on a 2-inch gage length.

A limited study of the properties of simulated repair welds, originally included in the scope of work of Mods 1 and 2 of this contract, was carried out. The welds tested in this portion of the study exhibited ultimate strengths slightly higher than the weldments prepared by the standard welding procedures.

D. Contract NAS8-1529, Mod 6 (27 June 1964 to 29 June 1965)

Contract NAS8-1529 Mod 6 extended the research program into the fourth year. Initially, the principle objective of this portion of the program was the development of welding techniques for X7106 aluminum alloy in various thicknesses. The work directed toward the development of these welding techniques was to include an investigation of both the MIG and TIG welding processes. Provision was made to include additional alloys in the program. The scope of work, as initially stated in Mod 6 of the contract, included the following specific topics:

(1) A literature and industrial survey related to the weldability of the X7106 alloy and similar alloys.

(2) Selection of optimum filler metal.

In this portion of the program, an investigation was to be carried out to provide the information necessary to select the optimum filler metal alloy from the commercially available filler materials suited to the welding of X7106 alloy.

(3) A study of the weldability of X7106 alloy.

In this portion of the work, both the MIG and TIG processes were to be employed, and consideration was to be given to the soundness of the welds produced by each process and to the mechanical properties obtained.

(4) Evaluation of weldments subjected to uniaxial and biaxial loading conditions.

The primary emphasis was to be placed upon the uniaxial properties of the weldment. Provision was made to generate enough biaxial data to attempt to obtain a relationship between the uniaxial and biaxial properties.

During the course of the program, the primary emphasis was shifted from the investigation of the weldability of X7106 alloy and the development of welding techniques to a study of biaxial and uniaxial properties of 2219-T87 and 2014-T6 weldments. This shift of emphasis was initiated by the NASA project manager and reflected the most immediate requirements of the SATURN program. As a result, the work related to X7106 alloy was more limited than that intended by the initial scope of work.

A survey of published literature and of information available from industrial organizations, related to the properties and the weldability of X7106 alloy, was conducted. This survey established the general state of knowledge in this particular area and served as a basis for the organization of the experimental program.

A study of the natural aging characteristics of 0.090-inch thick MIG and TIG X7106 weldments was conducted. Weldments made with three commercially available filler alloys (X5180, 5356, and 5556) were included in this study. A marked increase in the hardness and strength of the weld deposit and adjacent heat-affected base material occurred upon natural aging for periods in excess of eight weeks for all of the weldments studied. Of the combinations of welding process and filler metal included in the study of X7106 weldments, the TIG weldments, as a group, exhibited higher uniaxial tensile properties than those of the MIG weldments. Only slight differences in mechanical properties were noted among the weldments made with the three different filler alloys by either process.

The hot cracking characteristics of X7106-T63 weldments relative to those of 2219-T87 were also investigated. The results of these tests indicated that X7106-T63 is more susceptible to hot cracking during welding than 2219-T87. No significant difference in the crack susceptibility of the X7106-T63 weldments made with the three filler metals was noted.

The properties of MIG and TIG weldments of 2014-T6 and 2219-T87 aluminum alloys under biaxial and uniaxial loading conditions were measured and compared. The results of this study indicate that the TIG process is superior to the MIG process for the fabrication of 2014-T6. In the case of 2219-T87, no significant differences were noted in the average properties of TIG and MIG weldments. In the course of this portion of the program, a number of observations were made which indicate that the membrane stress formula, derived for a spherical shell, is not adequate for the determination of the aboslute value of biaxial ultimate strength from hydraulic bulge test data.

E. Contract NAS8-20160, Mod 1, Mod 2 (29 June 1965 to 29 April 1966)

Contract NAS8-20160 provided for a continuation of the work initiated under Contract NAS8-1529. The scope of work for this new contract included the following major items:

(1) The evaluation of the mechanical properties of weldments in high-strength aluminum alloys subjected to biaxial stresses.

This portion of the program was to include MIG and TIG weldments in 2014-T6, 2219-T87, and X7106-T63 aluminum alloys.

(2) Determination of the true ultimate strengths of biaxially loaded specimens subjected to bulge pressure tests and the establishment of the relationship between the biaxial properties and the uniaxial properties of aluminum alloy weldments.

(3) The development of welding techniques for X7106 aluminum alloy and the establishment of the optimum welding process-filler metal combination for this alloy.

(4) Further investigation of the susceptibility of X7106 aluminum alloy to hot cracking during welding.

A study of the biaxial strength of 2219-T87 parent metal and weldments using circular hydraulic bulge tests, cylinder tests, LTV and MIT biaxial tests was made. The results of this study established that the stress in welded panels subjected to bulge pressure tests is described by the equation

$$\sigma = KP^{2/3}$$

where

σ = biaxial stress, psi

P = bulge pressure, psi

K = material and geometry constant

A series of uniaxial and biaxial tests was conducted on 2014-T6, 2219-T87, and X7106-T63 parent metal and weldments. The results of these tests were combined with those from the previous year (Contract NAS8-1529 Mod 6) to provide a better statistical basis for a comprehensive analysis. Among the 2014-T6 weldments tested, the MIG weldments made with 4043 filler wire consistently exhibited the lowest mechanical properties. Considering the lower tolerance limits of both the uniaxial and biaxial ultimate strengths, the TIG 2014-T6/4043 and TIG 2014-T6/2319 weldments were comparable. In the case of 2219-T87 alloy, the MIG and TIG weldments (2319 filler wire) exhibited approximately equal properties. The TIG X7106-T63/X5180 weldments exhibited the highest uniaxial and biaxial strength of all the panels tested.

A study of the natural aging characteristics of MIG and TIG X7106-T63 weldments in thickness of 0.187 inch, 0.50 inch, and 1.00 inch, was performed. Significant increases in ultimate strength were observed for all types of X7106-T63 weldments aged for periods of 30 days or longer. For the two thinner gages, no significant differences were noted in the properties of MIG and TIG weldments. In the case of the 1.00-inch weldments, those fabricated by the TIG process exhibited significantly higher ultimate strengths than those made utilizing the MIG process.

The susceptibility of X7106-T63 weldments to hot cracking, initially studied in the previous year, was investigated further. The results of this study indicate that the crack susceptibility of X7106-T63 is comparable to that of 2014-T6 and that both of these two alloys are significantly more susceptible to hot cracking during welding than is alloy 2219-T87.

F. Conclusions

The principle conclusions drawn from the research program are summarized as follows:

(1) No significant improvement in the strength of weldments of Al-Cu alloys occurs as the result of aging at room temperature.

(2) Special precautions in joint design and joint preparation (including cleanliness) must be employed to assure sound welds in the high-strength aluminum alloys.

(3) Second phase precipitates, formed in the weld deposit and heat-affected base metal, play a significant role in the initiation of fracture of the welded joint.

(4) In the case of weldments of 2014-T6, 2219-T87, and X7106-T63 alloys, the biaxial ultimate strength is not significantly different from the uniaxial ultimate strength.

(5) Uniaxial test data are adequate for use in design of high-strength aluminum weldments.

(6) Hydraulic bulge tests may be utilized for the determination of the biaxial ultimate strength of parent metal and welded panels.

(7) MIG 2014-T6/4043 weldments exhibit the lowest uniaxial and biaxial ultimate strengths of those tested.

(8) TIG 2014-T6/4043 and TIG 2014-T6/2319 weldments exhibit equivalent mechanical properties.

(9) The mechanical properties of MIG 2219-T87/2319 and TIG 2219-T87/2319 weldments are comparable.

(10) In general, TIG weldments of 2014-T6 and 2219-T87 aluminum alloys exhibit ultimate strengths either higher than or comparable to MIG weldments. In addition, the MIG process is subject to erratic behavior and results in less control of weld bead size and shape.

(11) X7106-T63 aluminum alloy may be welded by both the TIG and MIG processes using procedures similar to those generally employed in the fabrication of high-strength aluminum alloys.

(12) TIG X7106-T63/X5180 weldments exhibit mechanical properties superior to those of 2014-T6 and 2219-T87 weldments after reasonably short periods of aging at room temperature.

III. PROCEDURES AND DISCUSSION OF RESULTS

A. Contract NAS8-1529, Mod 1 (7 February 1961 to 27 March 1962)

The work carried out under Mod 1 of Contract NAS8-1529 consisted of studying some of the variables which affect the strength of welded joints in high-strength aluminum alloys. The variables investigated were as follows:

(1) Weld contour, penetration and size of heat-affected zone (HAZ)

(2) Age hardening characteristics of parent metal, weld deposit and HAZ

(3) Diffusion of alloying elements between weld metal and HAZ.

In this portion of the research program, all work was confined to welding 0.090-inch thick 2014, 2024, and X2020 high-strength aluminum alloys. Both tungsten inert gas (TIG) and metallic inert gas (MIG) processes were used, although most efforts were directed toward the utilization of the TIG process. Detailed test data and precedures were previously reported in the First Annual Summary Report.(1)

1. Weld Contour, Penetration and HAZ Width

A study of travel speed, wire feed, positioner finger spacing, and back-up groove design was undertaken to show the influence of these parameters on weld contour, penetration and the width of heat-affected zone of TIG welds. As travel speeds and wire feeds were increased from 20 inches per minute to 70 inches per minute (other variables held constant), the weld bead was narrowed, the penetration was decreased and the width of the HAZ was slightly reduced.

A test series was also conducted with variations in the spacing of the copper hold-down fingers while other parameters were held constant. TIG 2014-T6 weldments were employed in this test series. The width of the HAZ for weldments made with a finger spacing of 1-1/4 inches was twice that resulting from a 1/2-inch spacing, as shown in Figure 1. This parameter was found to exert a more marked influence on the HAZ width than did travel speed.

The influence of the configuration of the groove in the copper backup bar heat-affected zone was evaluated. The configuration of the

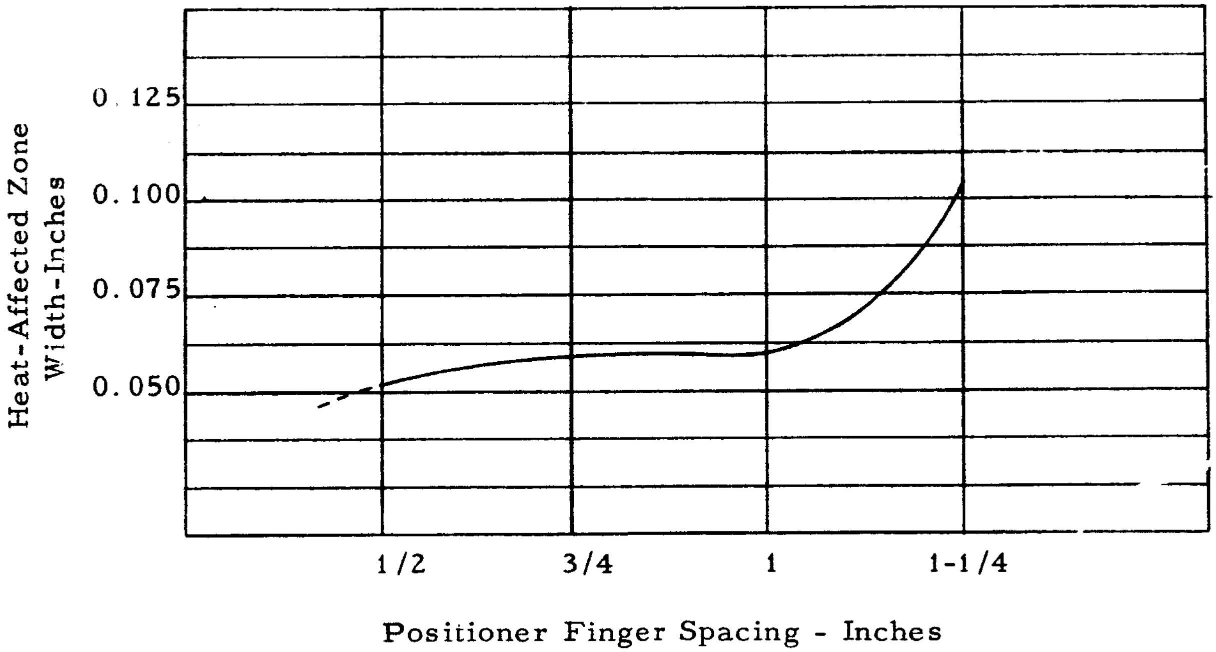


FIGURE 1. EFFECT OF POSITIONER FINGER SPACING ON THE HEAT AFFECTED ZONE WIDTH

backup bar plays the same role as hold-down finger spacing in that it influences the heat transfer from the weld zone. Early attempts were made to obtain complete penetration with no groove in the backup strip. Inconsistent penetration resulted, indicating that the bottom edge of the square-butt joint was being chilled too rapidly. Two backup bar groove designs, illustrated in Figure 2, were employed, and the V configuration produced the narrower HAZ.

In the early stages of the program, one of the major problems encountered was the occurrence of macroporosity and microporosity. The following steps were found to substantially eliminate the problem:

(1) Joint preparation - plate surfaces adjacent to the joint were scraped and the abutting edges were draw filed immediately prior to welding.

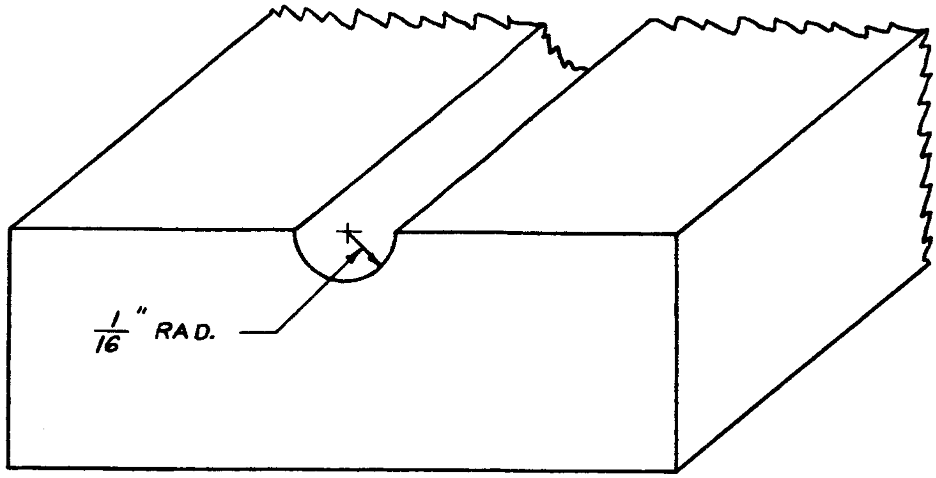
(2) Wire shield - the spools of welding wire were placed in shields on the welding equipment to protect them from atmospheric contamination.

In this particular case, involving relatively high travel speeds, the use of a preweld root gap of 0.018 inch aided in the prevention of porosity. A flow of helium gas in the groove of the backup bar was also employed to provide additional assurance of soundness.

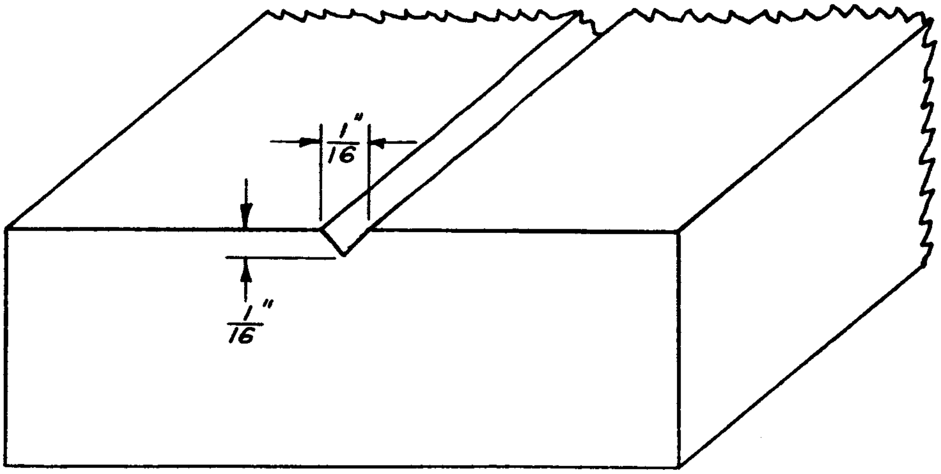
2. Age Hardening Characteristics

The strength and ductility of copper-bearing aluminum alloy weldments are affected by the $CuAl_2$ phase which precipitates in the matrix and grain boundaries as the weld solidifies from the molten state. A program was initiated to study this effect. Samples of 2014, 2024, and X2020 were heated to temperatures of 600°, 700°, 750°, 800°, 850°, 900°, and 950°F, held for fifteen minutes, and quenched in water. Hardness readings were taken at intervals during room temperature aging up to 120 hours. Typical results are shown in Figure 3. Metallographic examination of the samples indicated that the $CuAl_2$ phase agglomerated into large particles at temperatures of 650°F for 2024, 750°F for X2020, and 800°F for 2014 alloy. Similar studies on 2014-T6, 2014-T3, and X2020-T6 alloys were conducted to investigate artificial aging at 200°F and 300°F.

At room temperature, X2020 did not age harden at all, but significant increases in hardness were observed for 2024 and 2014 alloys quenched from temperatures in the range of 750°F to 950°F. Artificial aging of 2014 and X2020 produced an increase in hardness of those samples quenched from 750°F to 950°F, but the X2020 alloy was much more sluggish in its response to aging.

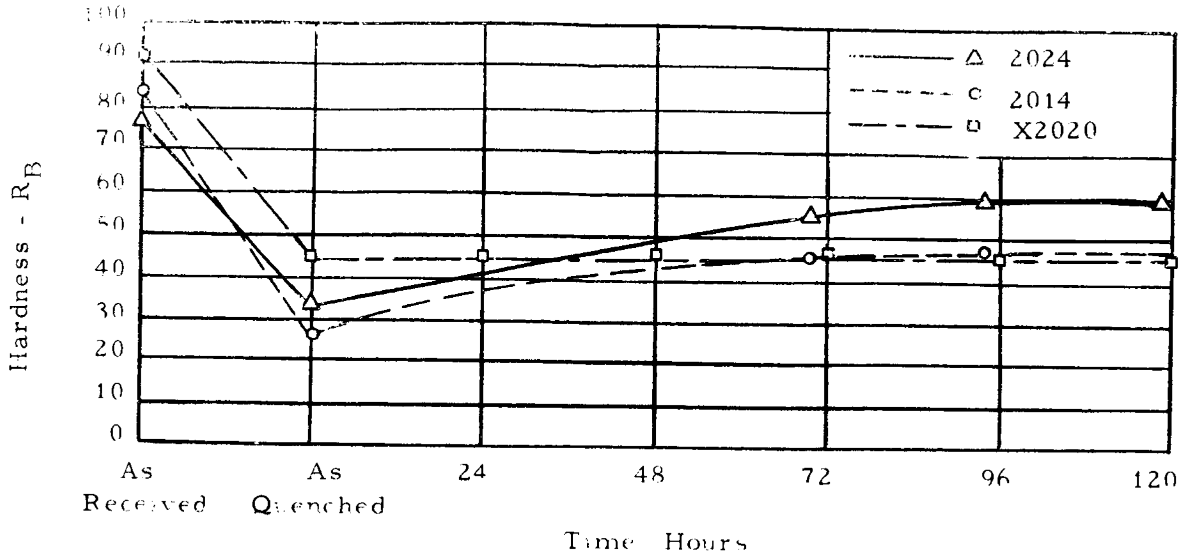


(a) Semicircular Groove

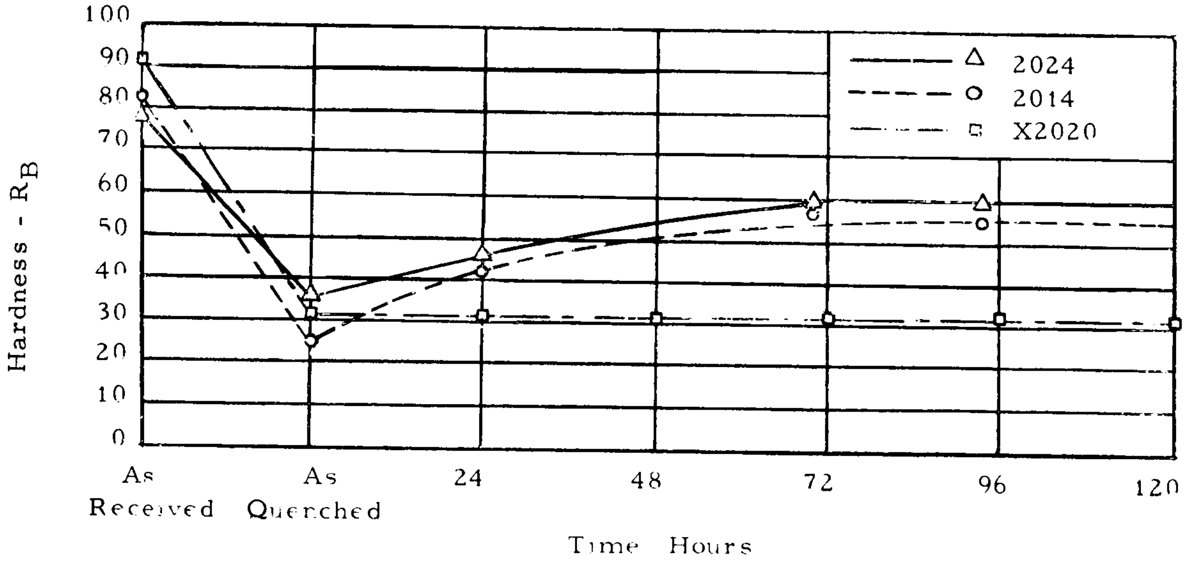


(b) V Groove

FIGURE 2. BACKUP STRIP GROOVE CONFIGURATIONS



(a) Quenched from 750°F



(b) Quenched from 800°F

FIGURE 3. AGING CHARACTERISTICS OF 2024, 2014, AND X2020 ALUMINUM ALLOYS

The aging characteristics of weld deposits in TIG 2014-T6 weldments made with 716 and 2319 filler wire were also studied. Natural aging at room temperature and artificial aging at 200°F and 300°F were employed. It was observed that 2319 weld deposits do not respond to aging as readily as 716 weld deposits, Figures 4 and 5.

A limited study of the aging characteristics of the weld deposits in 0.090-in 2014-T6 MIG weldments made with both 716 and 2319 filler wire was made. The results were similar to those obtained on TIG welds.

3. Diffusion Studies

Since there are substantial differences between the alloy content of the base metal and filler wire in many cases, a study of the tendency for diffusion of the alloying elements was undertaken. The various methods used were: (1) microhardness surveys, (2) wet chemical analysis, (3) x-ray fluorescent analysis, and (4) microradiography.

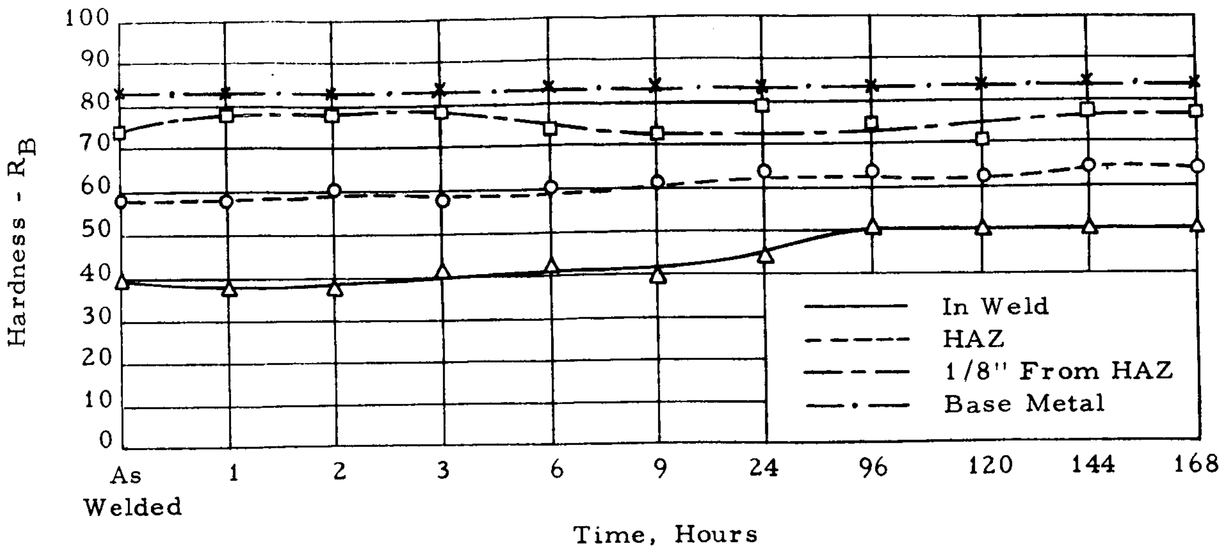
The test weld was made on 1/4-inch 2014 and 2024 base metal using a manual MIG process with 716 filler wire and a weave bead so that a sizeable sample of weld metal could be obtained for analysis.

Microhardness measurements were taken across the fusion lines. No marked changes in hardness near the fusion line, which would indicate that diffusion had occurred, were observed.

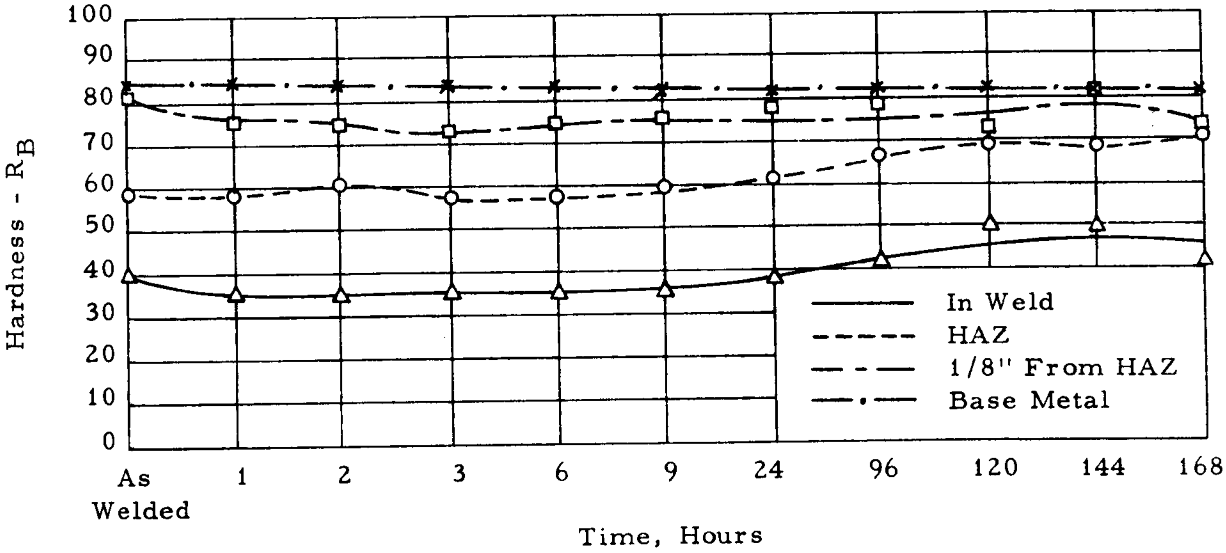
Wet chemical analysis for Si was performed on chips from successive 0.010-inch layers removed from a weld deposit specimen. The results were inconclusive, probably because of the small sample sizes and the lack of a uniform line of fusion.

X-ray fluorescent analyses were obtained at incremental depths of 0.002 inch on a weld-deposit specimen. No appreciable differences in element concentration across the fusion line were noted.

The region of the fusion line of the welds was studied using microradiographic techniques. Indications of zones in which the x-rays were more highly absorbed were noted on each side of the fusion line, suggesting that further development of this technique may be helpful in studies of diffusion processes in the vicinity of welded joints.

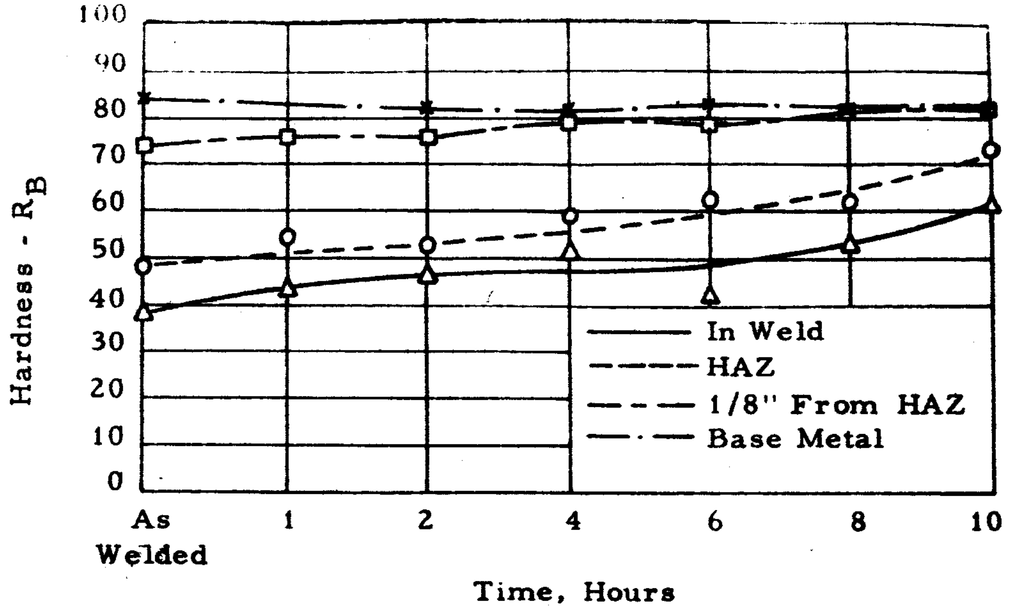


(a) 0.090-Inch TIG 2014-T6 Weldment, 716 Filler Wire

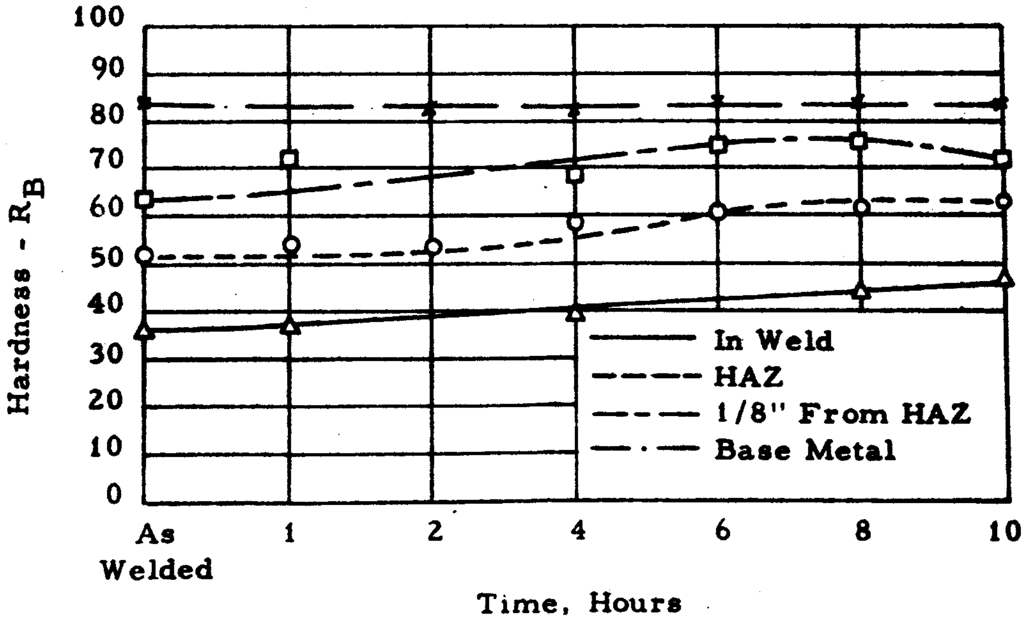


(b) 0.090-Inch TIG 2014-T6 Weldment, 2319 Filler Wire

FIGURE 4. NATURAL AGING CHARACTERISTICS OF ALUMINUM ALLOY WELDMENTS



(a) 0.090-Inch TIG 2014-T6 Weldment, 716 Filler Wire. Aged at 300°F.



(b) 0.090-Inch TIG 2014-T6 Weldment, 2319 Filler Wire. Aged at 300°F.

FIGURE 5. ARTIFICIAL AGING CHARACTERISTICS OF ALUMINUM ALLOY WELDMENTS

B. Contract NAS8-1529, Mod 2, Mod 3, and Mod 4 (27 March 1962 to 27 April 1963)

During the second year of the program, the emphasis was switched to the study of techniques for welding 3/4-inch 2219-T87 high-strength aluminum alloy. Also, a study was made to develop an improved filler metal for this alloy for the purpose of increasing joint strength efficiency. The equipment and procedures used for these investigations are described in the Second Annual Summary Report.(2)

1. Welding Techniques

In this portion of the program, essentially all welding was performed in the horizontal position using the MIG process and a specially designed fixture, Figure 6. A number of welding parameters were investigated, but 3/32-inch diameter, 2319 filler wire was used exclusively. Initial welds were made on panels with edges prepared by sawing and buffing with a wire disc. This technique proved to be unsatisfactory because of the excessive porosity produced. An improved preparation procedure, consisting of milling the edge, and draw filing immediately prior to welding, eliminated the porosity. Defects resulting from incomplete fusion were also encountered. This problem was eliminated by reducing the land at the root of the double V and by employing a root gap of 0.020 inch. The final joint configuration employed in this portion of the program is shown in Figure 7.

A series of weldments were fabricated, from which tensile test coupons were removed to evaluate flat versus horizontal position weld, 90° versus 60° double V joints, argon versus helium-argon shielding gas, and the effect of cold wire feed. The only significant effect on ultimate tensile strength noted was the reduction in strength resulting from the use of cold wire feed. The cold wire feed had been successfully used to reduce the amount of "sagging" of the weld puddle which occurs naturally when welding in the horizontal position, Figure 8. However, the scope of the year's program did not permit the development of optimum welding parameters for use with cold wire feed.

Explosion bulge tests were run on one parent and one welded 2219-T87 panel. On both plates, the cracks ran into the hold-down regions, where only elastic deformation occurs, and the fracture surfaces exhibited full shear.

2. Filler Metal Development

A program was established for evaluating the effects of four elements (Cu, Mn, Ag, and Si) on the age hardening characteristics of aluminum.

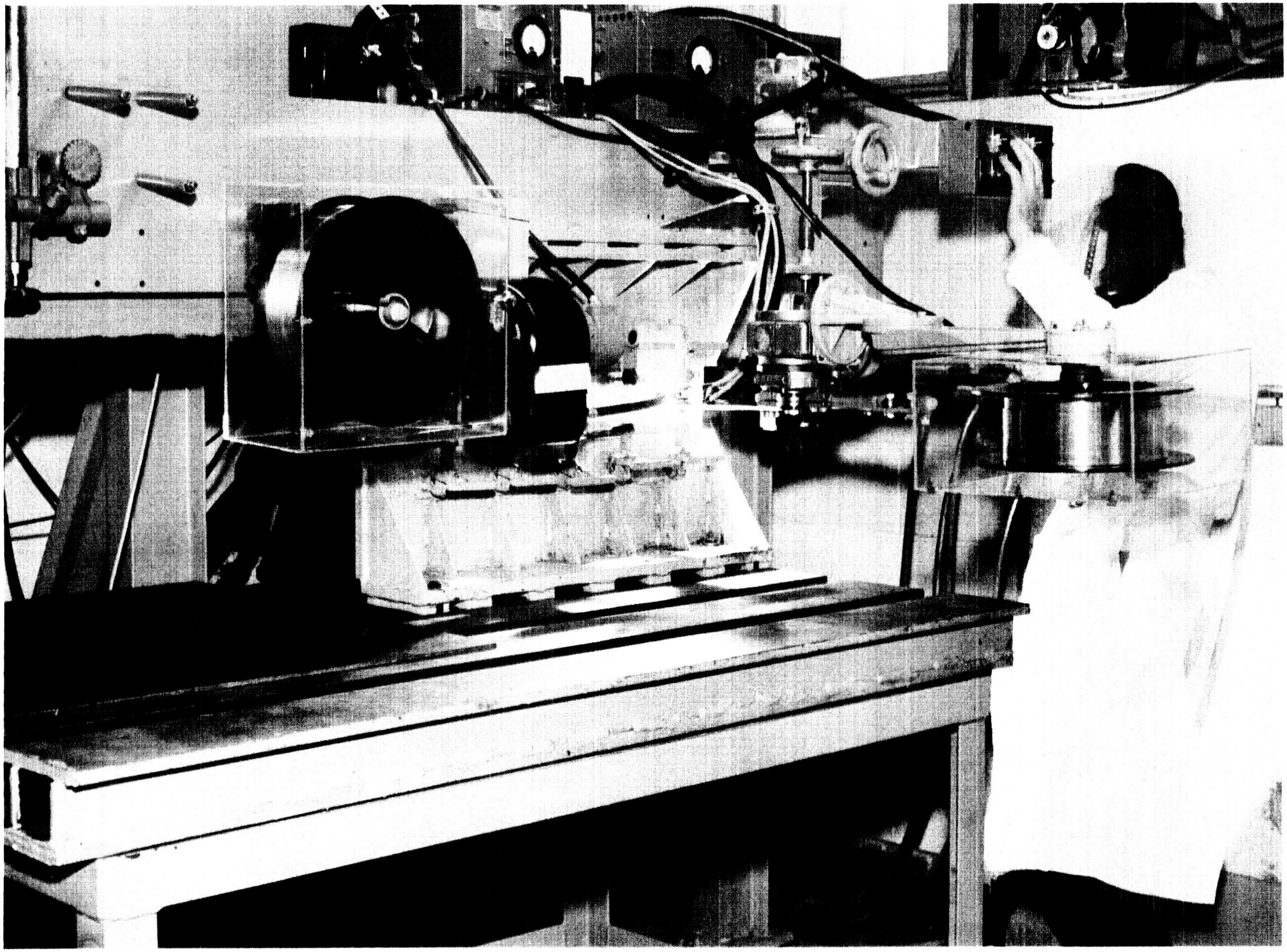


FIGURE 6. MIG WELDING EQUIPMENT SET UP IN HORIZONTAL POSITION. Note cold wire feed attachments.

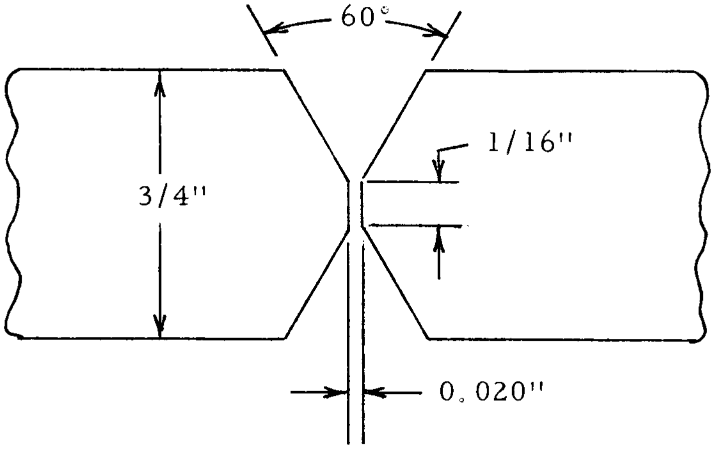
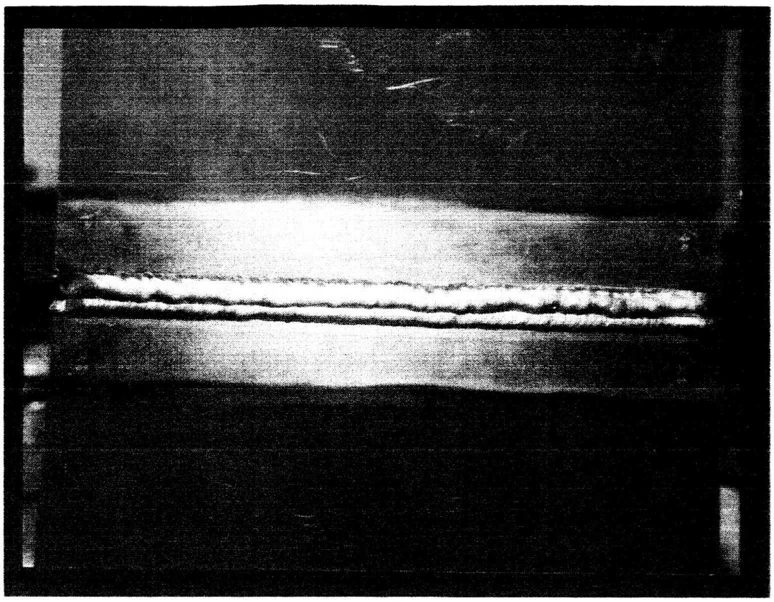
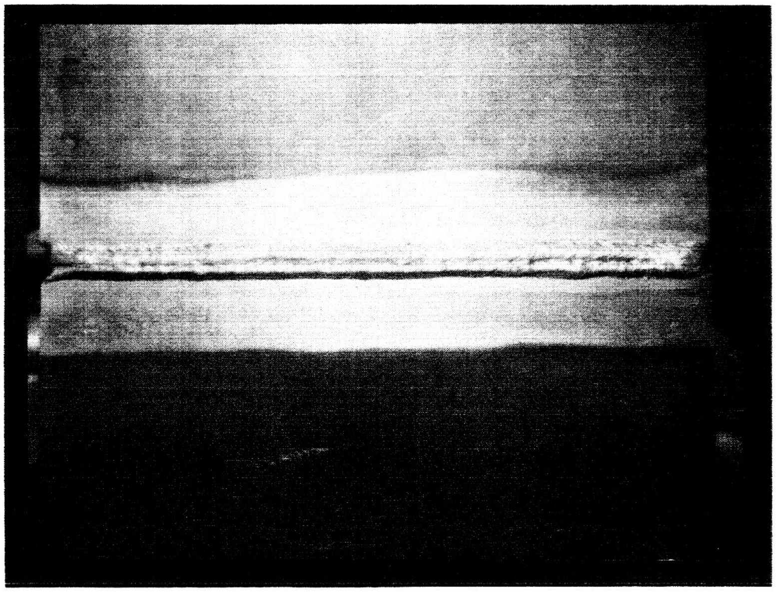


FIGURE 7. 60° DOUBLE "V" GROOVE DESIGN



(a) Horizontal Weld Coupon
without Cold Wire Feed



(b) Horizontal Weld Coupon
with Cold Wire Feed

FIGURE 8. COMPARISON OF "SAGGING" OF WELD BEAD WITH AND WITHOUT COLD WIRE FEED

Four heats of Al-Cu alloys, containing 1.0%, 3.0%, 5.0%, and 6.5% Cu, were made. Specimens of these alloys were solution treated and artifically aged at 325°F. As expected, a higher hardness level was attained as the copper content was increased from 1.0% to 6.5%. Four additional Al-Cu alloys, containing 3.25% to 7.36% Cu, were prepared and drawn into 3/32-inch wire for welding. Beads were deposited on 2219-T87 aluminum plate with these alloys and with 2319 filler metal for comparison. The addition of copper increased the hardness of the welds, but none of them hardened significantly on aging at room temperature. The hardness of the 2319 weld deposit was comparable to that of deposits made with the 6.35% and 7.36% Cu alloys.

Four heats of Al-Mn alloy, containing from 0.13% to 1.0% Mn, were drawn into welding wire and deposited on 2219-T87. Weld deposits of these alloys were much softer than those of the Al-Cu alloys, but the Al-Mn alloys age hardened somewhat in a two-week period at room temperature.

A similar process was used to evaluate Mn, Ag, and Si in concentrations up to 1.0% in a Al-6.5% Cu base alloy. The Mn and Ag had no measurable effect on the hardness or aging characteristics of the weld metal. Si, in concentrations up to 0.3%, appeared to provide a slight increase in hardness.

Based on the results previously obtained, the following composition was chosen for analysis as a potential filler alloy:

Copper	6.5%
Silicon	1.0%
Silver	1.0%
Manganese	0.5%
Zirconium	0.15%
Vanadium	0.10%
Aluminum	Balance

An ingot of this composition was drawn into 3/32-inch diameter filler wire. Test panels were prepared, using a U-groove design instead of a double-V groove, with the new alloy and with 2319 filler wire. Tensile tests were performed on specimens from each plate and the following average strengths were obtained:

	0.2% YS	UTS	% Elong
Experimental Alloy	22,400	30,600	1.7
2319 Filler Metal	33,300	40,200	4.2

The panel welded with experimental wire was also found to have considerable porosity.

A metallographic examination of specimens of all of the experimental alloys previously described was carried out. As expected, the amount of $CuAl_2$ precipitate increased with increasing copper content as shown in Figures 9 and 10. In the aluminum-manganese alloys, the presence of an $MnAl_6$ phase was noted. In general, the addition of any of the four elements investigated resulted in additional second-phase particles in the microstructure.

The experimental alloys did not prove to be as satisfactory for welding alloy 2219-T87 as the commercially available type 2319 filler wire.

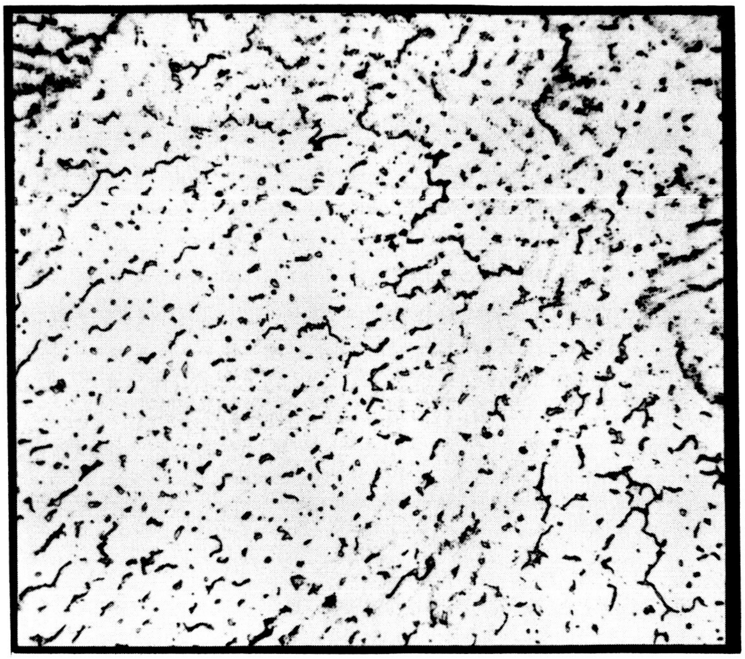
The influence of the addition of copper directly to the molten weld puddle on the properties of welded joints was also studied. In this study, bead-on-plate weld deposits were made employing the MIG process with copper cold wire feed. The rate of feed of the copper wire was varied to produce weld beads with nominal copper concentrations of 12, 21, 31, and 36 percent. The bead crowns were then machined off, and the hardness of the weld deposit and the adjacent heat-affected zone was measured.

No significant increases in hardness on aging at room temperature were noted for any of the weld deposits; however, the hardness of the weld deposit increased significantly with increasing copper content. Transverse cracks developed in the beads made with a copper addition of 36 percent.

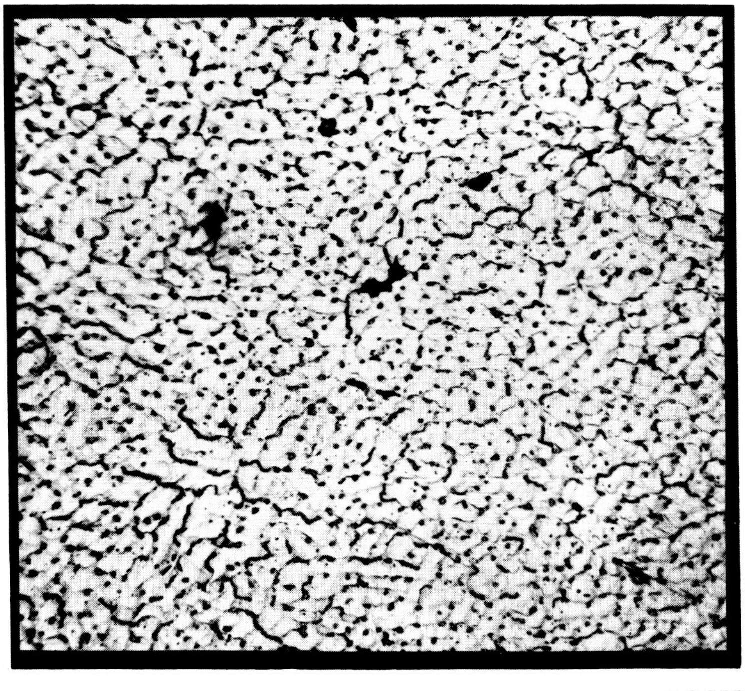
A MIG 2219-T87 weldment was prepared with a copper cold wire feed to give nominal copper concentration of 12 percent. Tensile specimens, containing the welded joint, were cut from the panel and a cross section of the weld was examined metallographically. Large globules of undissolved copper were observed in the weld deposit, and the tensile specimens exhibited an average ultimate strength of 34,800 psi, 2,500 psi below that of a weldment prepared without the addition of copper.

C. Contract NAS8-1529, Mod 5 (27 April 1963 to 26 June 1964)

During the period covered by Mod 5 of Contract NAS8-1529, work was continued on the weldability of 3/4-inch 2219-T87 high-strength aluminum alloy. The program included a metallurgical study of the weld zones, a study of failure mechanisms under uniaxial and biaxial loading, an investigation of the yield behavior of weldments, and an evaluation of the effect of explosion impact loading on the properties of welds. Details of the test procedures and data obtained are contained in the Third Annual Summary Report.(3)

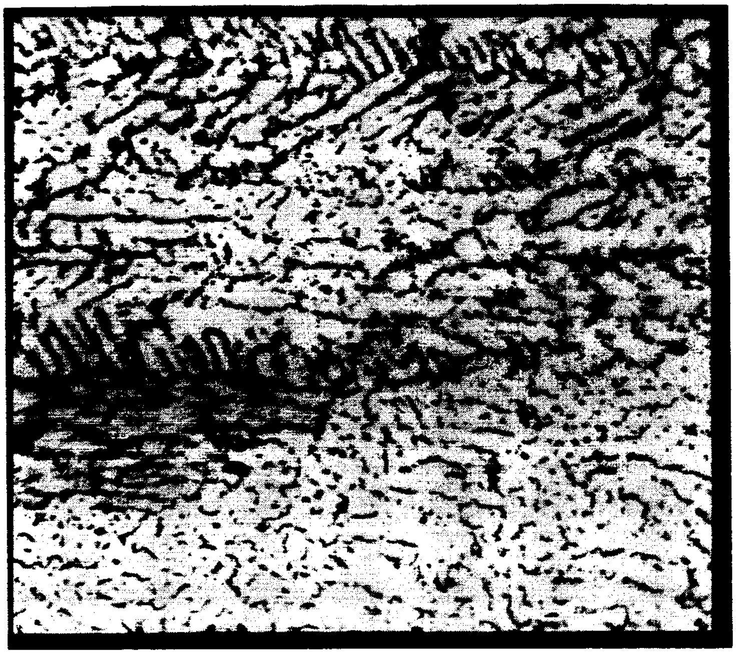


(a) Al-3.25% Cu Filler Wire



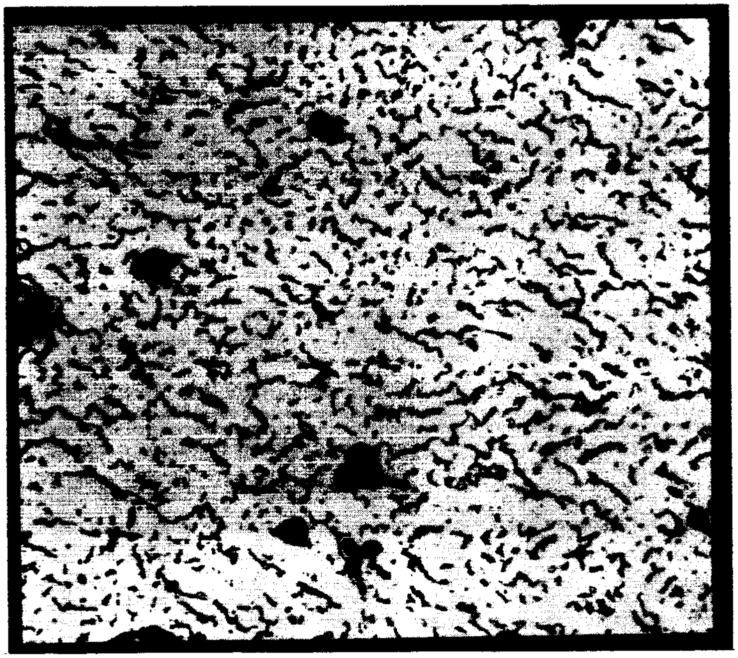
(b) Al-4.25% Cu Filler Wire

FIGURE 9. MICROSTRUCTURE OF WELD BEADS MADE WITH Al-Cu ALLOY FILLER WIRE



500X

(a) Al-6.36% Cu Filler Wire



500X

(b) Al-7.36% Cu Filler Wire

FIGURE 10. MICROSTRUCTURE OF WELD BEADS MADE WITH Al-Cu ALLOY FILLER WIRE

1. Weld Zone Investigation

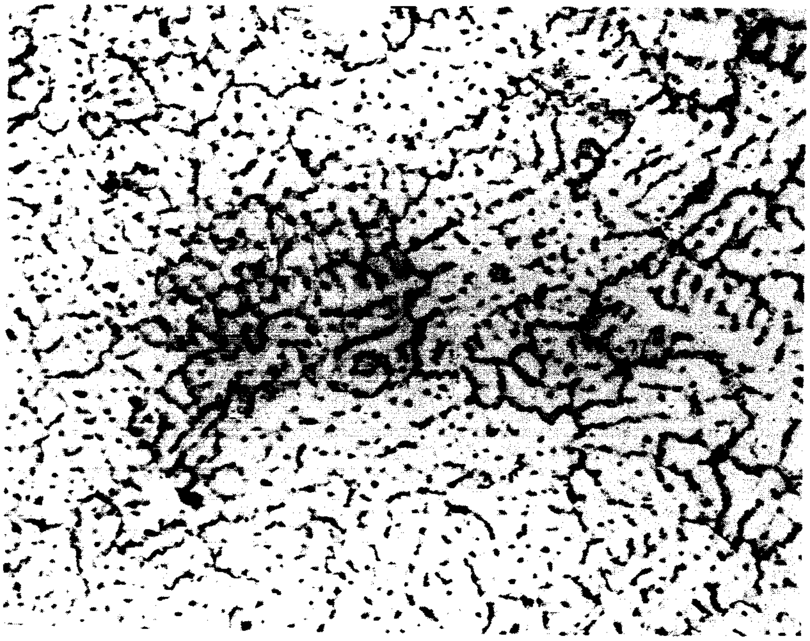
The mechanical properties of the 2219 alloy are dependent on the manner in which the $CuAl_2$ precipitate is dispersed in the weldment. The microstructure of the parent metal in the fully heat treated (T87) condition was compared to structures produced in various parts of the HAZ and weld metal. The finely dispersed and agglomerated $CuAl_2$ in the parent metal was quite different from the form of the precipitate found in the weld metal and heat-affected base metal, Figures 11 and 12. A needle-like precipitate, tentatively identified as β(Al-Cu-Fe), was observed in the toes of the weldments. The typical weld crown profile in this region is shown in Figure 13, and the microstructure is illustrated in Figure 14.

2. Study of Failure Mechanisms in Aluminum Alloy Weldments under Uniaxial and Biaxial Loading

Uniaxial tensile specimens machined from a 3/4-inch thick 2219-T87 welded panel were tested with the weld crowns intact. These weldments were prepared using a square butt joint design and welded in the horizontal positional using one weld pass on each side. The gage section was 1/4 inch × 3/4 inch × 4-1/2 inches and symmetrical about the weld. The fracture path, the same in all cases, ran from the "toe" of the first weld pass diagonally to the opposite "toe" of the second pass. A few specimens were incrementally loaded to determine the stress required to initiate cracking. These were found to occur at 92-97 percent of the ultimate tensile strength (no cracking was found at the 0.2 percent offset yield stress) and were located in the "toe" region of the first pass. A few tests were conducted on specimens with the crown removed, and,in these cases, the fracture occurred completely within the weld metal. In another group of tests, minimum heat fusion passes were run along the weld "toes". This reduced the severity of the geometric notch, improved the microstructure, increased the uniaxial strength and moved the failure path into the weld metal. A simulated weld repair panel was also prepared by making an additional fusion pass over a portion of the original weld and tested. Uniaxial tensile specimens from this panel exhibited ultimate tensile strengths comparable to or slightly higher than those of the standard panels.

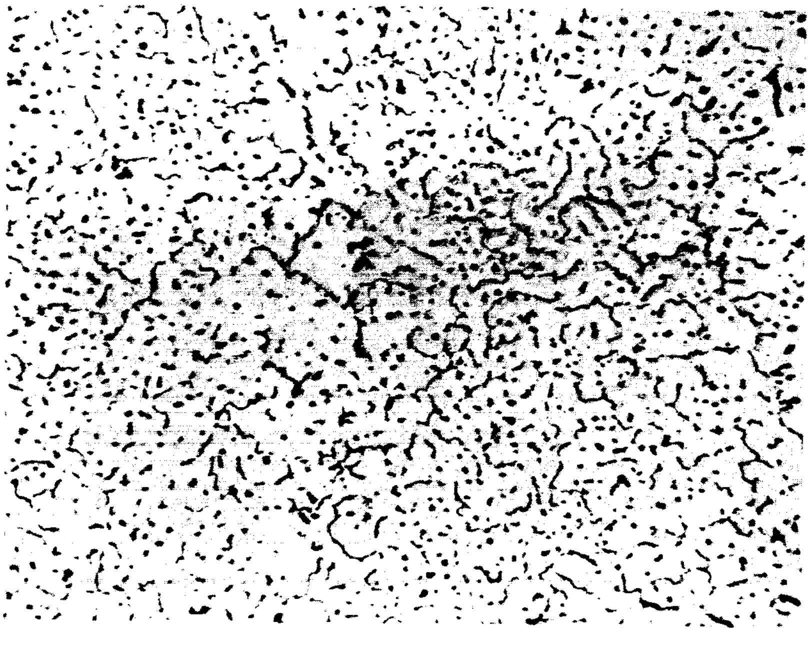
The technique of electron fractography was employed in the study of the failure mechanisms. Fractographs illustrating typical topography of parent and weld metal fractures are shown in Figures 15, 16, and 17. The following observations were made in this study:

(1) Tensile fracture of 2219-T87 base metal and weldments occurred generally by the nucleation of microvoids at



Etchant-Keller's 250X

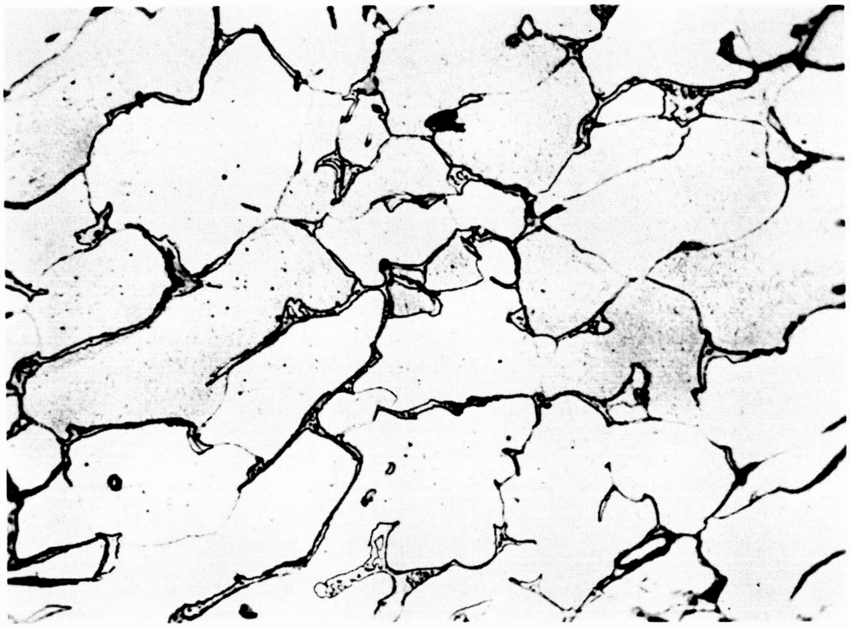
(a) First Pass



Etchant-Keller's 250X

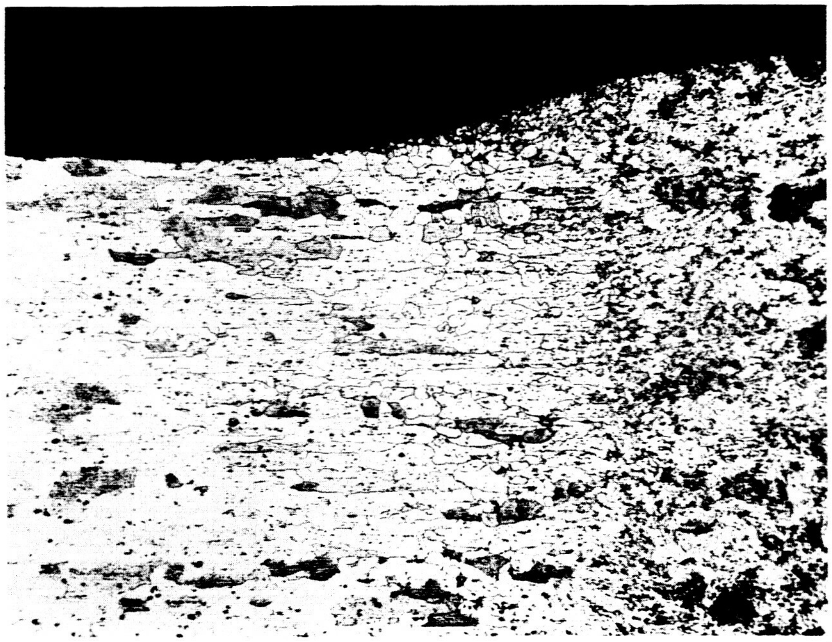
(b) Second Pass

FIGURE 11. MICROSTRUCTURE OF WELD METAL IN FIRST AND SECOND PASSES OF A 2219-T87 WELDMENT



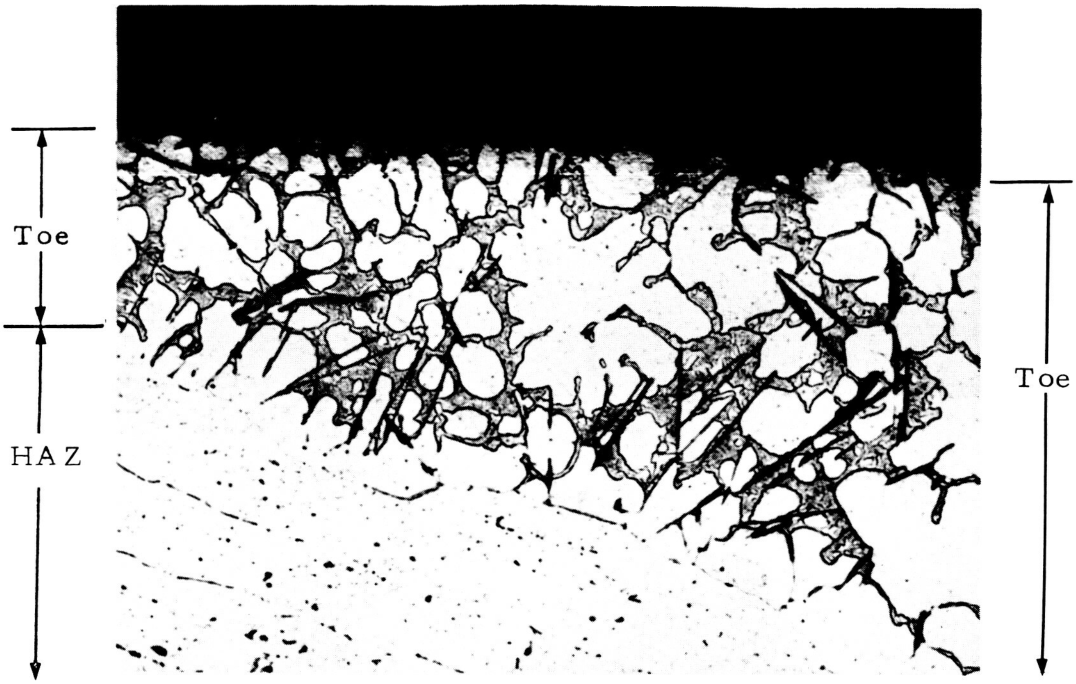
Etchant-Keller's 1000X

FIGURE 12. MICROSTRUCTURE OF HEAT-AFFECTED BASE METAL IN A 2219-T87 WELDMENT



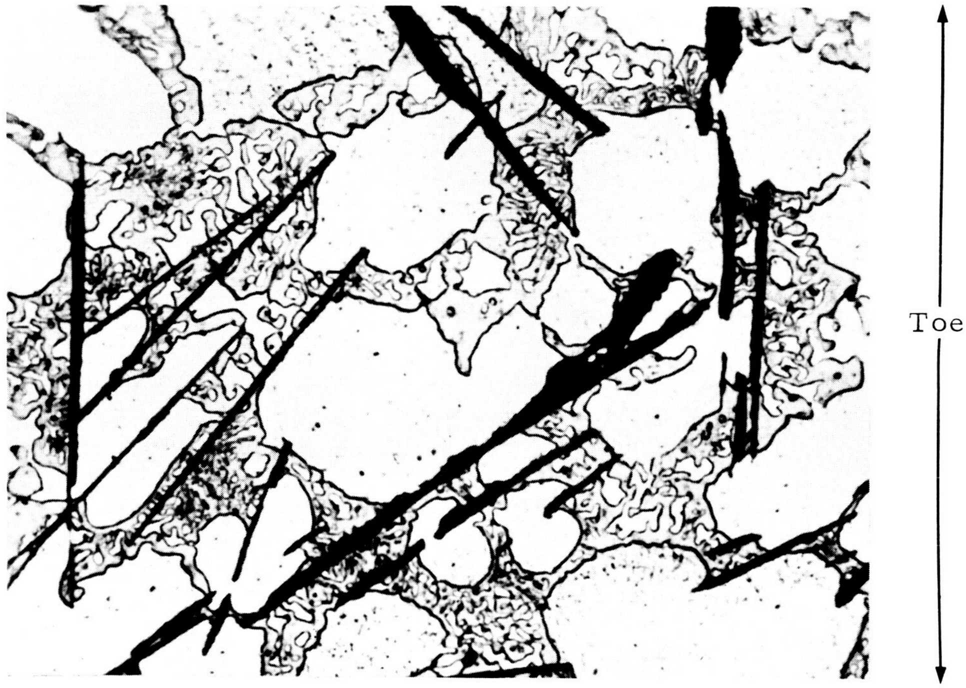
HAZ Weld
Etchant-Keller's 50X

FIGURE 13. WELD CROWN PROFILE AT THE TOE OF A 2219-T87 WELDMENT



Etchant-Keller's 500X

(a)



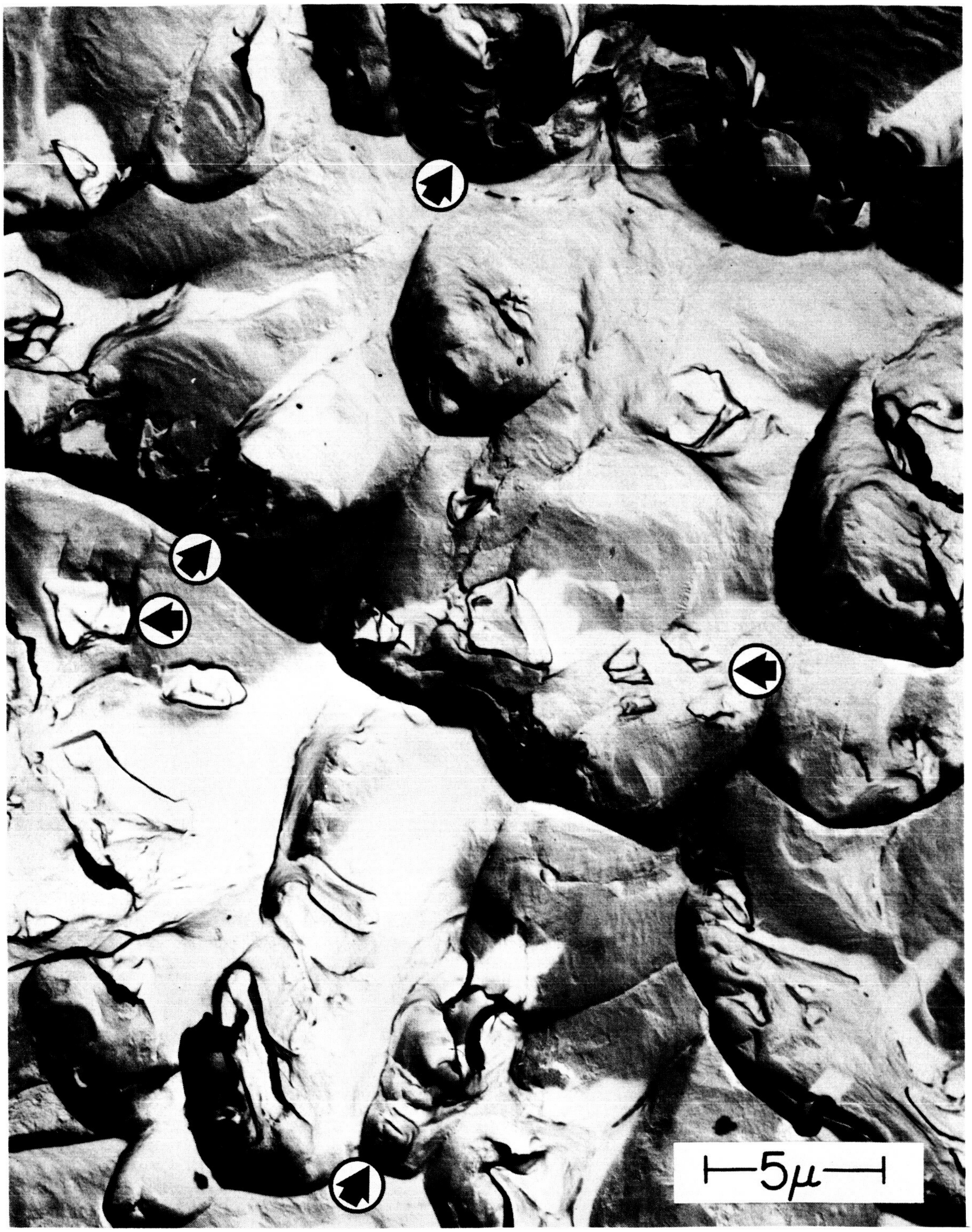
Etchant-Keller's 1500X

(b)

FIGURE 14. INTERMETALLIC CONSTITUENTS IN THE TOE OF A 2219-T87 WELDMENT

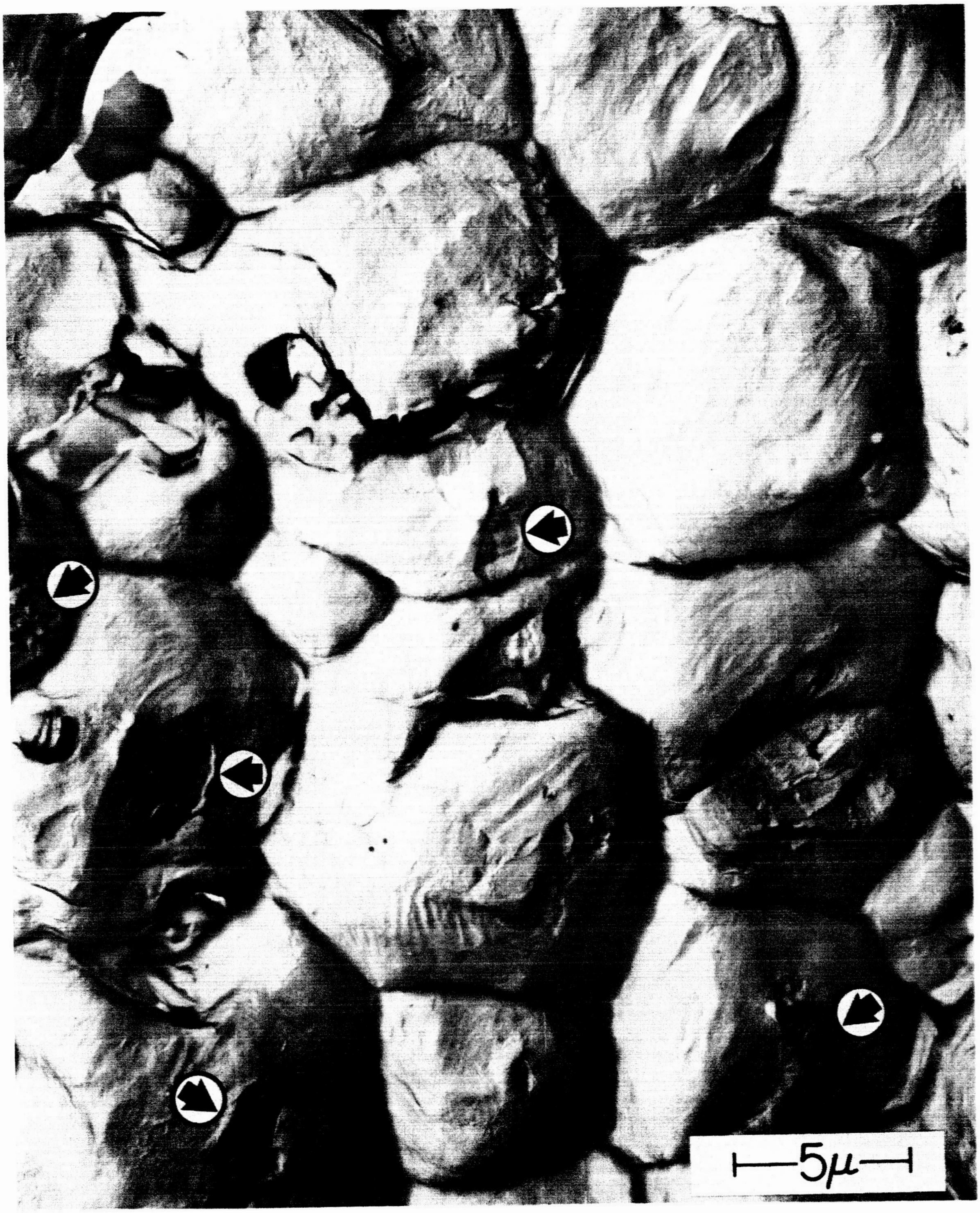
Two-Stage Plastic Carbon Replica 5000X

FIGURE 15. FRACTURE SURFACE OF 2219-T87 BASE METAL TENSILE SPECIMEN. (Fractograph taken in central "fibrous" region. Note the range of size of dimples. Arrows indicate origin of larger dimples at second-phase platelets.)



Two-Stage Plastic Carbon Replica 6000X

FIGURE 16. FRACTURE SURFACE OF 2219-T87 WELDED JOINT TENSILE SPECIMEN. [Specimen tested with weld crowns machined off. Fractograph taken from location near root of weld passes. Note irregular shape of shear dimples (oblique arrows) and dispersed second-phase particles in fracture surface (horizontal arrows).]



Two-Stage Plastic Carbon Replica 6000X

FIGURE 17. FRACTURE SURFACE OF 2219-T87 WELDED JOINT TENSILE SPECIMEN. (Specimen tested with weld crowns machined off. Fractograph taken from location near root of weld passes. Note the large, uniform equiaxed dimples. Arrows indicate origin of voids at second-phase platelets.)

inclusions and second-phase particles followed by the growth of these voids during plastic deformation

(2) The size, shape and distribution of second-phase particles exert a marked influence on the initiation and growth of voids

(3) There was a distinct difference in void shape and distribution in parent metal and weld metal fractures, and

(4) Massive second-phase particles at the "toe" of the welds played a significant role in the initiation of the uniaxial tensile failures.

Circular hydraulic bulge tests were conducted to investigate the fracture characteristics under biaxial conditions. Four test panels, 32 inches × 32 inches were tested as described in Appendix E. Two 3/4-inch, single butt welds and a 3/4-inch T butt weld with the crowns intact and one 3/4-inch single weld with the crowns removed were tested. The fracture path through the thickness was similar to that observed in uniaxial test specimens. In each case, the cracks were arrested in the vicinity of the hold-down region of the test die, where the panel is subjected to elastic strains. The similarity between uniaxial and biaxial fracture modes was also borne out by both optical metallographic and electron fractographic examinations.

3. Methods for Measuring Yield Strength and Ductility of Welds

The yield strength of a metal which does not exhibit a well defined yield point is usually taken as the stress producing 0.2 percent plastic deformation, more commonly known as the 0.2 percent offset yield strength. When the standard test method is applied to a heterogeneous test section consisting of weld metal, heat-affected zones and parent metal, the measured strain is the sum of the incremental strains contributed by the various components. At an applied stress greater than the yield strength of the weakest part, the strain distribution over the length of the gage section could be quite nonuniform. A series of uniaxial tensile specimens, with strain gages applied to the weld metal, HAZ and parent metal, were tested to investigate the extent of this condition. The results showed that, at the 0.2-percent offset (extensometer) stress, the weld metal had reached a plastic strain of nearly one percent and the parent metal had not begun to yield, Figure 18.

Another series of uniaxial tests was conducted to determine the strain distribution at failure. The various weld zones were located by chemical etching and microhardness traverses before testing. After fracturing

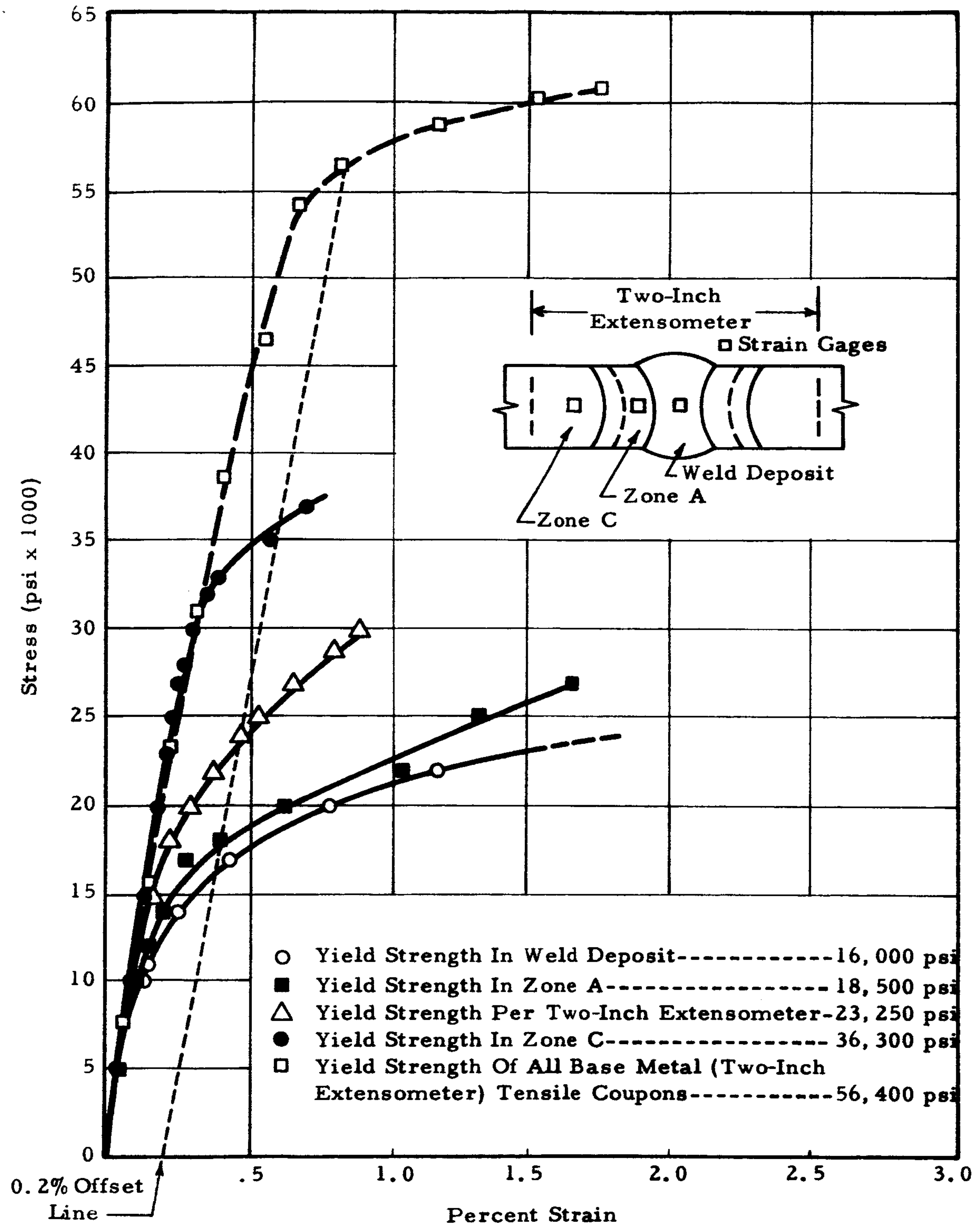


FIGURE 18. STRESS-STRAIN CURVES OF WELD DEPOSIT, ZONE A, ZONE C, AND PER TWO-INCH EXTENSOMETER OF TENSILE COUPON. [Note all base metal (two-inch extensometer) curve from different tensile coupon.]

the specimens, the halves were mated together and the zones were again measured. The results, summarized in Figure 19, also show that a large amount of the total strain occurs in the weld metal.

4. Explosion Impact Treating of Weldments

Two 3/4-inch × 12-inch 2219-T87 weldments were explosion impact treated as shown in Figure 20. Weld metal tensile specimens, cut from the weldment along the axis of the weld, and transverse tensile specimens containing a section of the welded joint were prepared and tested. The results of these tests and tests on similar specimens from an as-welded panel are as follows:

	Average Yield Strength (0.2% Offset), (ksi)			Average Ultimate Strength, (ksi)			Average Elongation (% in 2 in.)		
	No Charge	2 lb Pentolite	4 lb Pentolite	No Charge	2 lb Pentolite	4 lb Pentolite	No Charge	2 lb Pentolite	4 lb Pentolite
Weld Metal	14.2	30.8	33.1	39.3	41.6	41.4	19.3	19.3	10.1
Transverse Weld Specimen	22.0	30.8	32.7	40.5	40.3	41.9	5.1	4.5	5.7
Parent Metal	54.9	53.3	52.1	66.4	64.2	63.1	13.7	14.5	12.4

As may be noted in the above data, marked increases in the yield strength of both the weld metal and transverse tensile specimens resulted from the explosive impact treatment. No significant changes in ultimate strength were observed. In the case of the panel treated with the grooved back-up plate, the gain in yield strength occurred without any sacrifice of tensile elongation. The ductility of the panel using a flat back-up plate was reduced, apparently as a result of the gross plastic deformation imparted to the weld metal in this case. Microhardness surveys across the top (explosion side) and bottom (die side) of each weld showed only small increases in the hardness. The largest increase was noted on the bottom (die side) of the panel impacted against a flat plate, as might be expected from the larger amount of plastic deformation experienced in this zone.

D. Contract NAS8-1529, Mod 6 (27 June 1964 to 29 June 1965)

In the fourth year of this research program, the emphasis was placed on determining the uniaxial and biaxial mechanical properties of 1/8-inch 2219-T87 and 2014-T6 MIG and TIG weldments and studying the weldability of a new Al-Mg-Zn alloy, X7106. Detailed test data and descriptions of test equipment and procedures are given in the Fourth Annual Summary Report.(4)

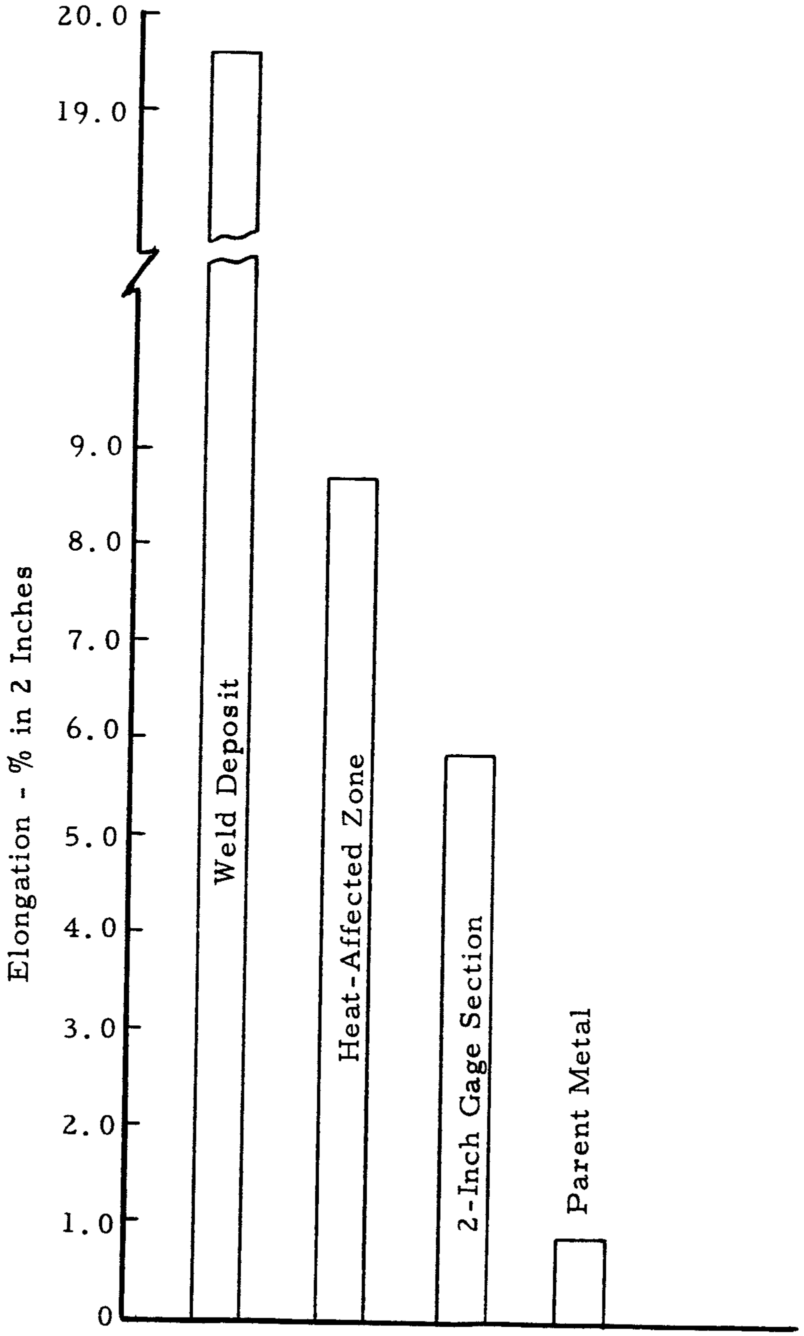
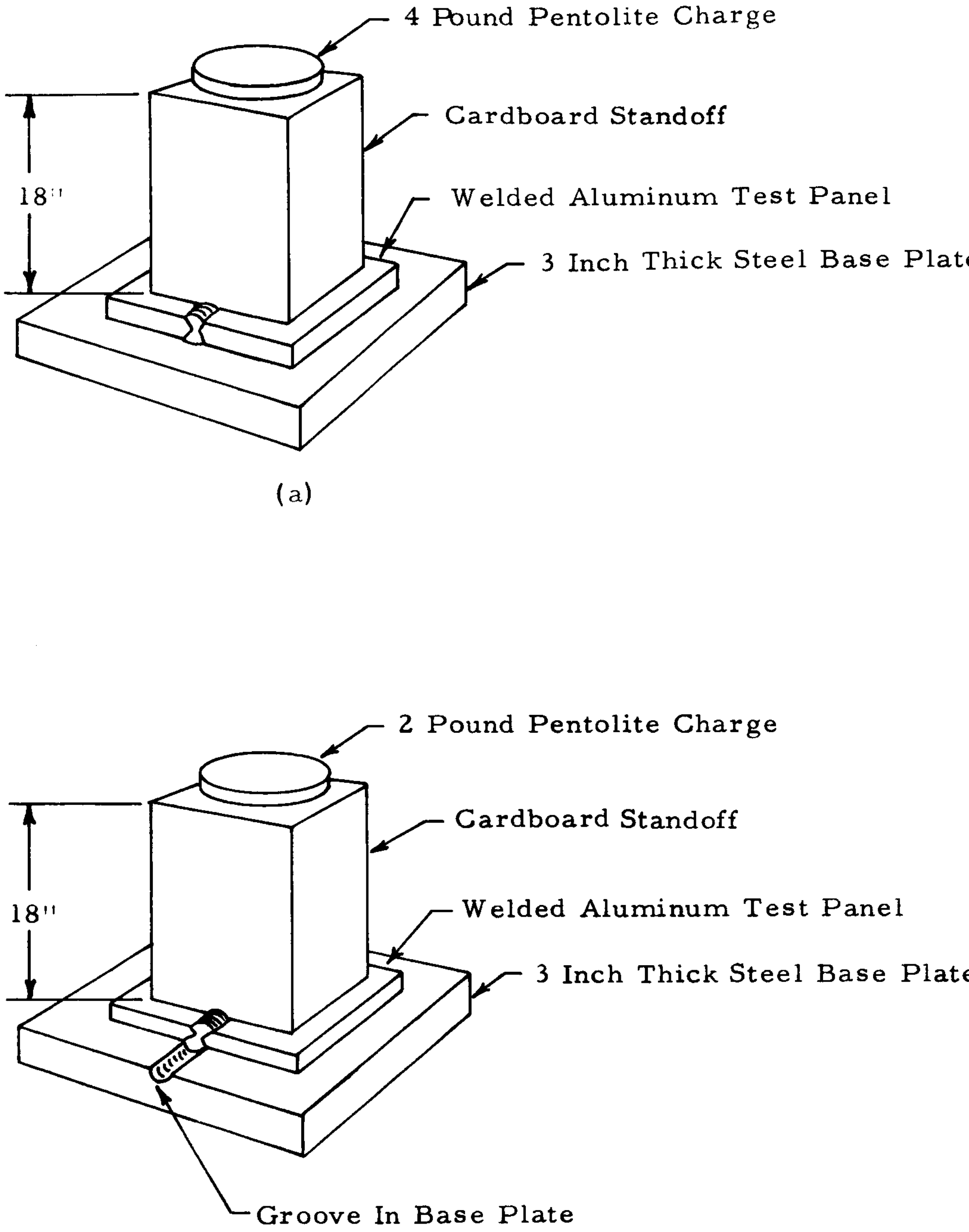


FIGURE 19. ELONGATION AT FRACTURE MEASURED IN VARIOUS ZONES OF A 3/4-INCH 2219-T87 WELDMENT



(a)

(b)

FIGURE 20. EXPLOSIVE IMPACT LOADING OF BUTT-WELDED TEST PANELS

1. Welding Process Evaluation

The evaluation of the TIG and MIG processes was carried out on the basis of the mechanical properties of weldments of the following process combinations:

Process	Alloy	Filler Metal
TIG	2014-T6	2319
TIG	2014-T6	4043
MIG	2014-T6	4043
TIG	2219-T87	2319
MIG	2219-T87	2319

Single welds, tee welds, and cross welds were subjected to uniaxial and biaxial loading conditions. The biaxial strengths were determined with the circular bulge test using the membrane stress equation, $\sigma = PR/2t$. The low biaxial strengths obtained led to the initiation of an investigation into the applicability of this equation to the circular bulge test. Sufficient information was gathered to show the need for a more thorough study of the use of the bulge test for the determination of biaxial strength. Although the indicated values of biaxial strength might be in error, the effect of changes in welding process, filler metal, etc., could be examined by this technique.

The mean values of the biaxial and uniaxial strengths, along with standard deviations and lower tolerance limits, are presented in Figure 21. These results show that, for 2014-T6/4043 weldments, the TIG process produced stronger welds than did the MIG process. The TIG 2014-T6/2319 and TIG 2014-T6/4043 weldments had essentially the same uniaxial strength, but those with 2319 filler had biaxial ultimate strength significantly higher than that of all other combinations. No significant differences were observed in the mean values of biaxial and uniaxial ultimate strengths for the MIG 2219-T87/2319 and TIG 2219-T87/2319 weldments. However, the biaxial lower tolerance limit for the MIG process was significantly higher than for TIG because of the higher degree of scatter observed in the biaxial test results on TIG 2219-T87/2319 welds. All of the conclusions based on biaxial strength are subject to the limitations of the applicability of the membrane stress equation.

In the course of the test program, it was observed that the uniaxial mechanical properties of the 2014-T6/4043 TIG and MIG weldments exhibited a higher degree of scatter than did the other types.

An investigation was conducted to study the effects of residual stresses on the biaxial to uniaxial strength ratio of weldments. Residual

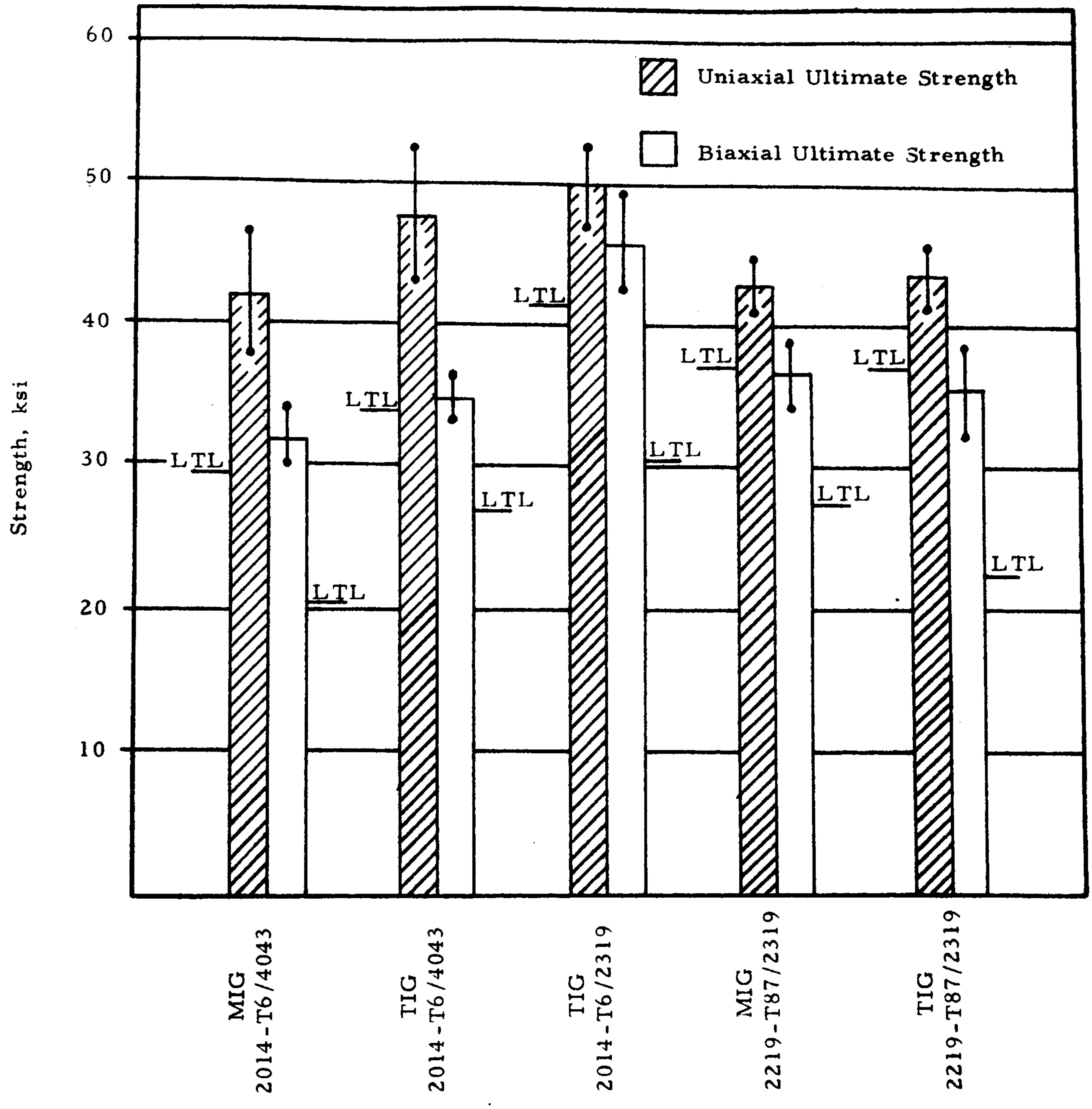


FIGURE 21. AVERAGE UNIAXIAL AND BIAXIAL ULTIMATE STRENGTHS FOR MIG AND TIG WELDMENTS

stress measurements were made on as-welded panels utilizing strain gages to determine the relaxation occurring in specimens cut from the panels. These measurements indicated the presence of tensile stresses parallel to the length of the weld of the order of the yield strength.and smaller tensile or compressive stresses perpendicular to the weld. Stresses induced from clamping in the welding fixture were generally lower in magnitude although considerable variation in these values was evident. Uniaxial and biaxial tests were run on annealed parent metal, as-welded TIG 2219-T87/2319, annealed TIG 2219-T87/2319 weldments, and on an as-welded TIG 2219-T87/2319 welded panel with crowns removed and multipass TIG 2219-T87/2319 panel in the as-welded condition. The results were that all of the above conditions had essentially the same biaxial/uniaxial strength ratio, indicating that neither residual stresses nor stress concentrations associated with the weld crown affected this ratio. Removal of the weld crown slightly lowered both the uniaxial and biaxial strength, and annealing significantly lowered these properties, as might be expected. The multipass welds had essentially the same biaxial to uniaxial strength ratio as the single pass weldments.

2. Weldability of X7106-T63 Aluminum Alloy

A survey of the literature pertaining to the 7000 series aluminum alloys was conducted, and visits were made to several industrial plants and laboratories to consolidate the available information on the weldability of the X7106 alloy.

Uniaxial tensile properties measured for four thicknesses of X7106-T63 alloy are given in Figure 22. Of the four thicknesses, the 0.187-inch material was the strongest and 0.090 inch the weakest. The longitudinal properties were higher than the transverse properties in all cases except for the 0.090-inch material.

The microstructures of each of the four thicknesses were examined. Typical structures observed in the 0.090-inch and 1.0-inch thicknesses are shown in Figures 23 and 24. The microstructure of the 0.187-inch material was similar to that of the 0.090-inch sheet, and those from the 0.050-inch and 1.00-inch plates were comparable. The grain boundaries of the two thinner materials were clearly defined and appeared to be outlined by an intermetallic precipitate. No such features were observed in the two thicker sections.

A uniaxial tensile test program was conducted to study the natural aging characteristics of X7106-T63 weldments made with three filler metals (X5180, 5356, and 5556). The results on TIG X7106-T63/X5180 weldments are shown in Figure 25 as being typical of the rate of aging observed. A summary of the properties of MIG and TIG weldments after 24 weeks of aging are given

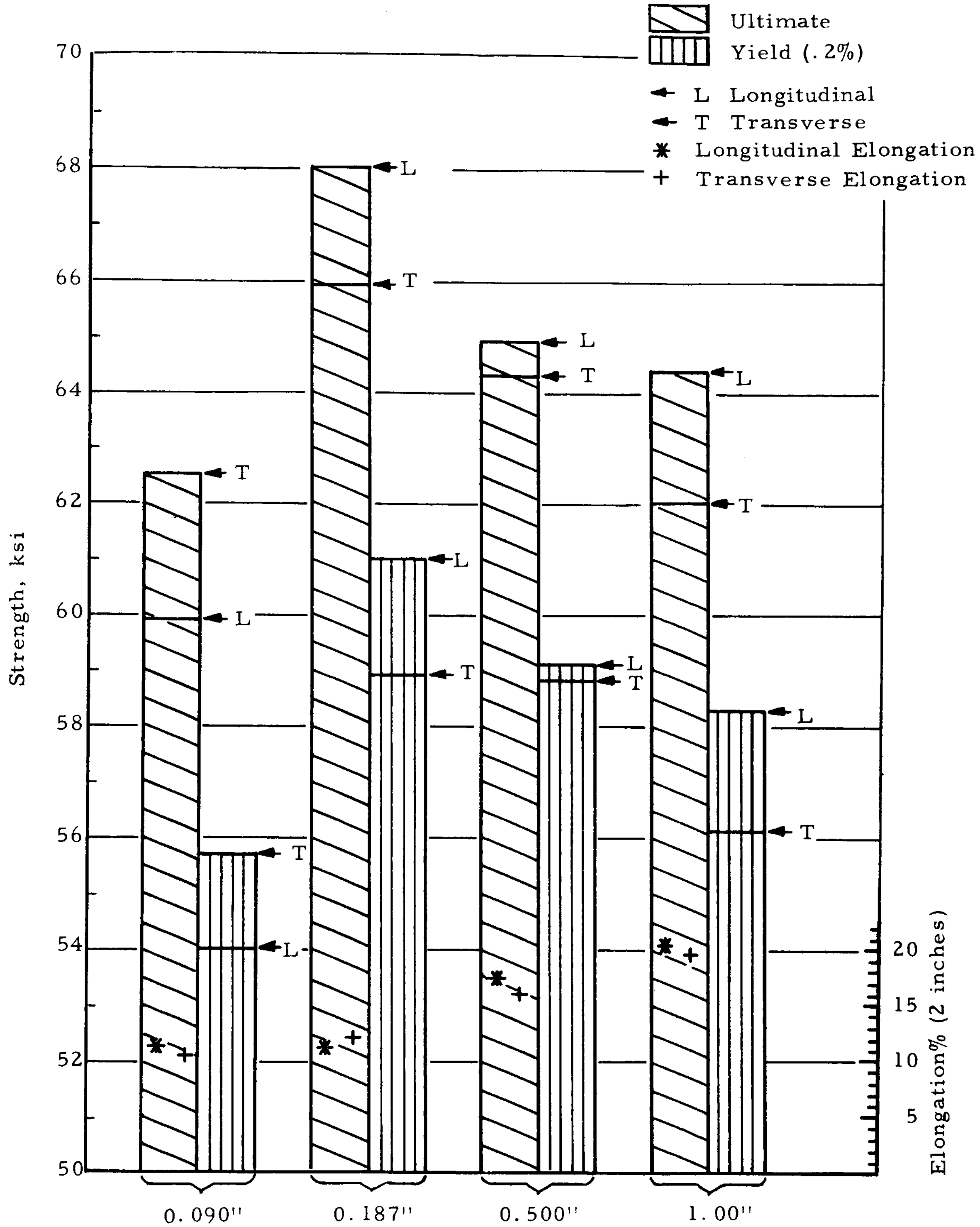
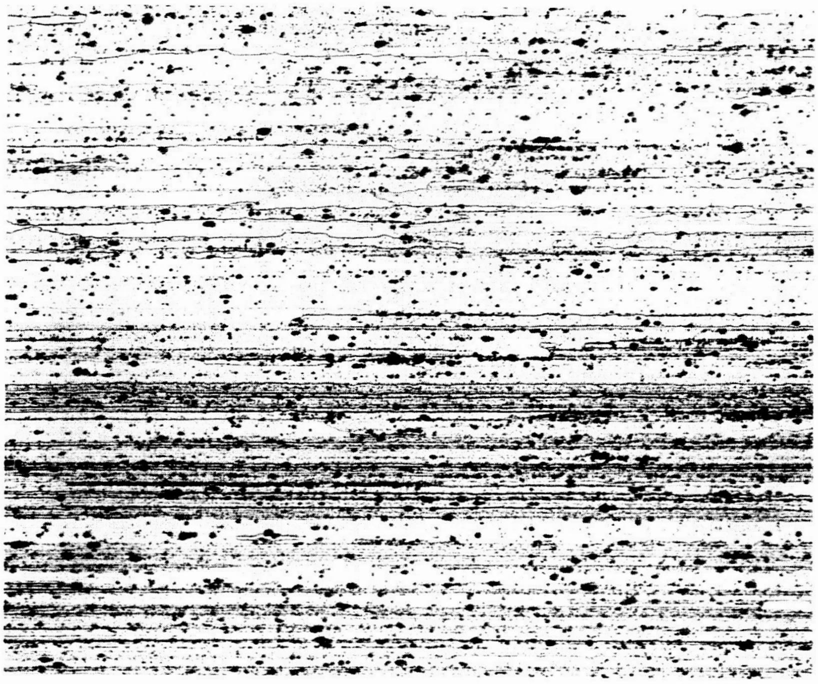


FIGURE 22. BAR GRAPH OF MECHANICAL PROPERTIES OF VARIOUS THICKNESSES OF X7106-T63



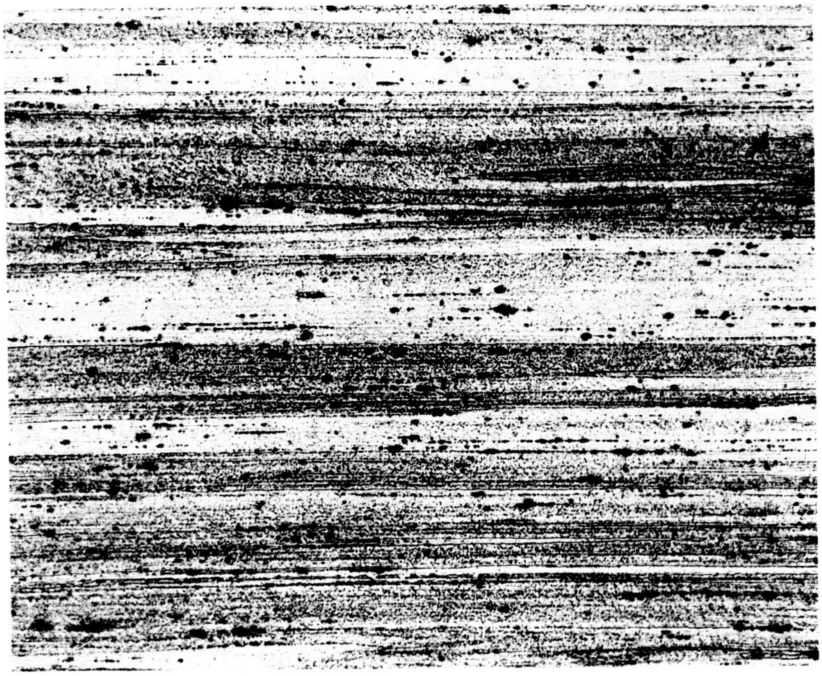
100X

(a)

Etchant-Keller's 1500X

(b)

FIGURE 23. MICROSTRUCTURE OF X7106-T63 0.090-INCH SHEET



100X

(a)

Etchant-Keller's 1500X

(b)

FIGURE 24. MICROSTRUCTURE OF X7106-T63 1.00-INCH PLATE

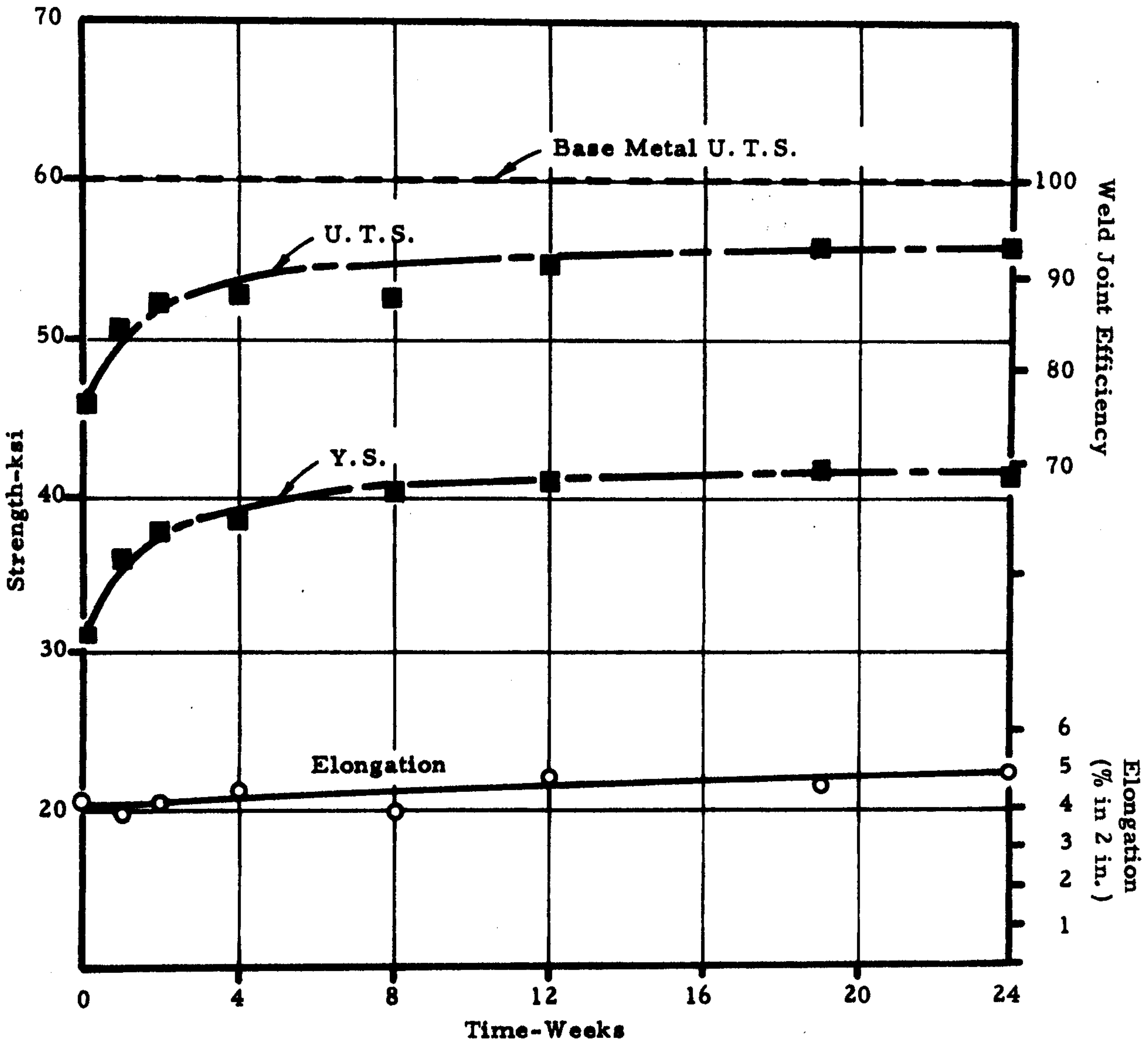


FIGURE 25. MECHANICAL PROPERTIES OF TIG-X7106/X5180 WELDMENTS

in Figure 26. As a group the TIG weldments exhibited higher ultimate strengths than the MIG weldments. In addition, the degree of scatter was less for TIG welds, resulting in significantly higher values of the lower tolerance limit of ultimate strength. The yield strengths of the MIG weldments were either comparable to or slightly lower than those of the TIG weldments. Of the group of TIG weldments, those made with 5556 filler wire exhibited a significantly lower ultimate strength than the other two (X5180 and 5356). All three MIG weldments had approximately equal tensile properties.

All of the failures occurred at one of two locations; within the HAZ or at the fusion line. The fusion line failures occurred predominantly after one day of aging for the TIG X7106-T63/X5180 and TIG X7106-T63/5356 weldments and after four weeks of aging of TIG X7106-T63/5356 weldments. In the specimens which failed in the HAZ, the fractures were located in a region between 0.08 inch and 0.32 inch from the fusion line. Metallographic examination revealed secondary cracks at the toes of the welds in many cases, some of which extended along the fusion line, as shown in Figure 27.

Microhardness surveys conducted on panels aged from two to eight weeks showed that a region of low hardness existed approximately 1/8 inch from the fusion line, corresponding to the general location of failure in the HAZ. The weld metal was softer, but the reinforcement of the crowns apparently more than offset this weakness. No significant differences were noted in the age hardening of the HAZ of MIG and TIG weldments, but the TIG deposited weld metal reached a higher hardness than the MIG after eight weeks aging time.

A series of Houldcroft crack susceptibility tests was performed on 0.090-inch X7106-T63 and 2219-T87 specimens. The results indicate that the X7106-T63 alloy is more susceptible to hot cracking during welding than the 2219-T87 alloy, as shown in Figure 28.

The temperature distribution in the vicinity of welded joints was determined with the aid of temperature sensitive crayons. A typical result is illustrated by Figure 29. This figure shows that the heat-affected zone, as revealed by chemical etching, consists of material heated to a temperature of 500°F or higher during the welding operation. It was apparent then, from the results of this study and other data in the literature, that the location of failures in X7106-T63 weldments may be associated with a region of base metal which was overaged during the welding operation.

E. Contract NAS8-20160 (29 June 1965 to 29 April 1966)

The fifth year of the program for developing welding techniques and filler metals for high-strength aluminum alloys was devoted to the determination

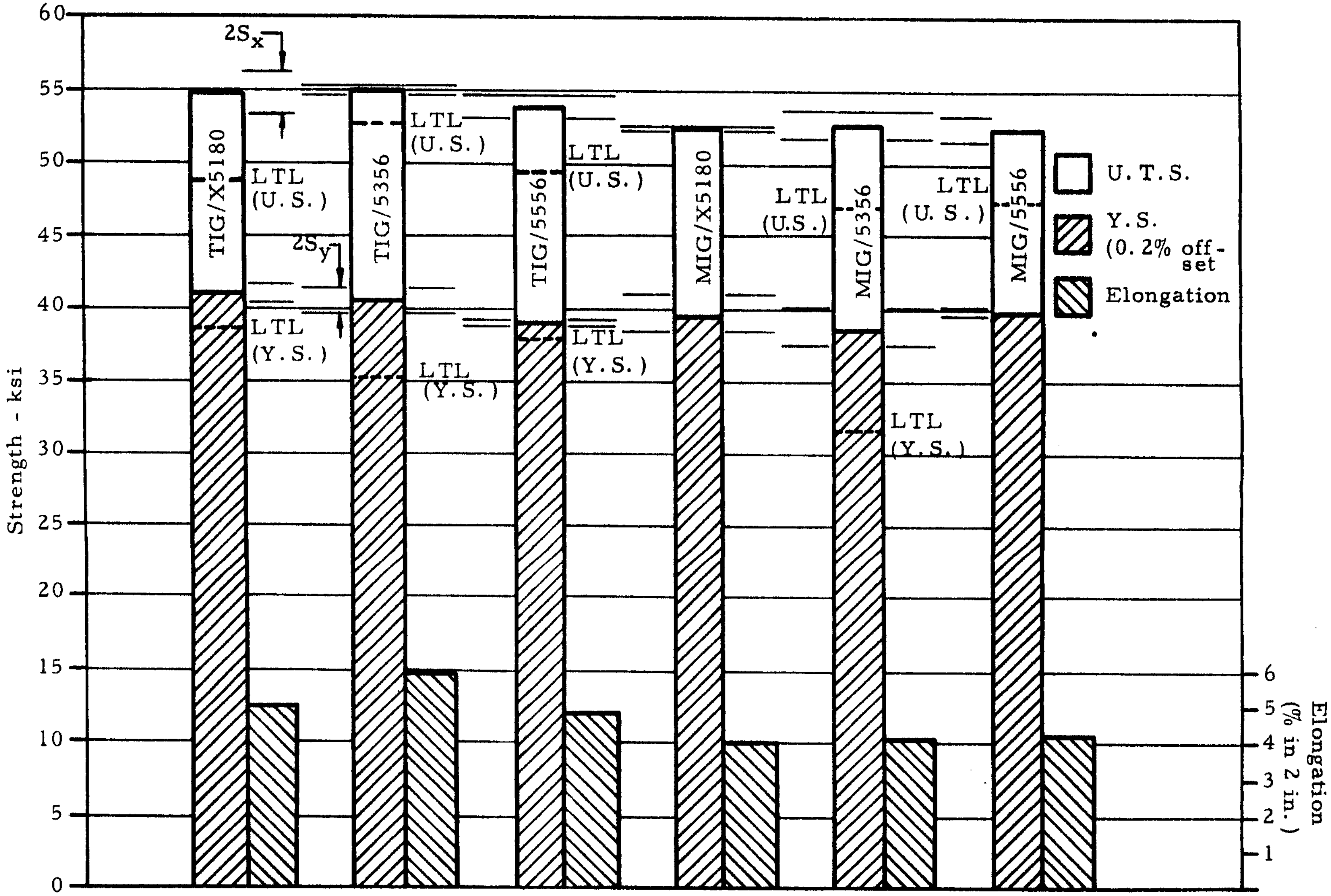


FIGURE 26. AVERAGE MECHANICAL PROPERTIES OF X7106-T63 WELDMENTS AGED 24 WEEKS

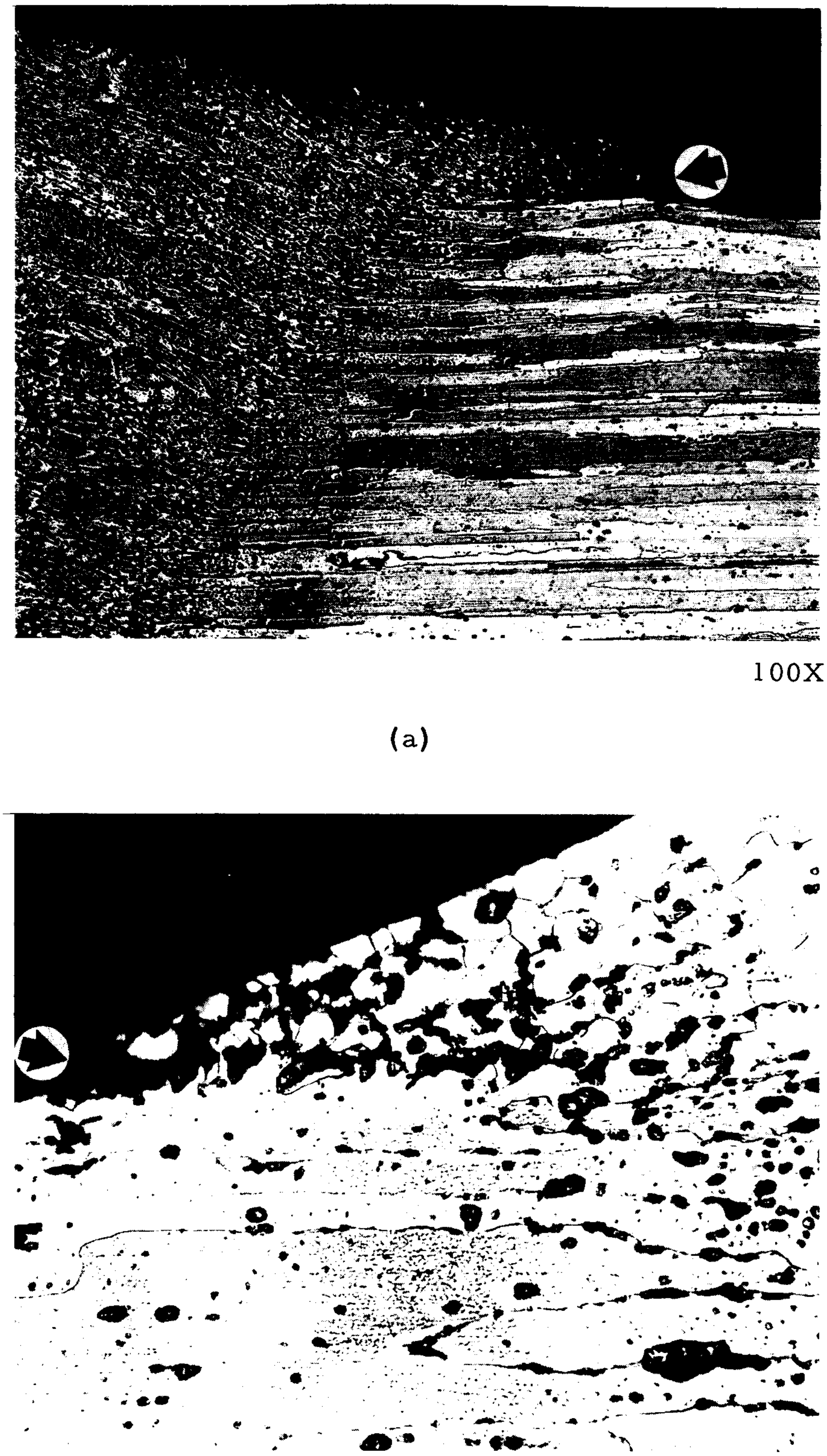


FIGURE 27. TOES OF WELD CROWN OF A MIG X7106 TENSILE SPECIMEN THAT FAILED IN THE HEAT-AFFECTED BASE METAL (Arrows indicate secondary cracks.)

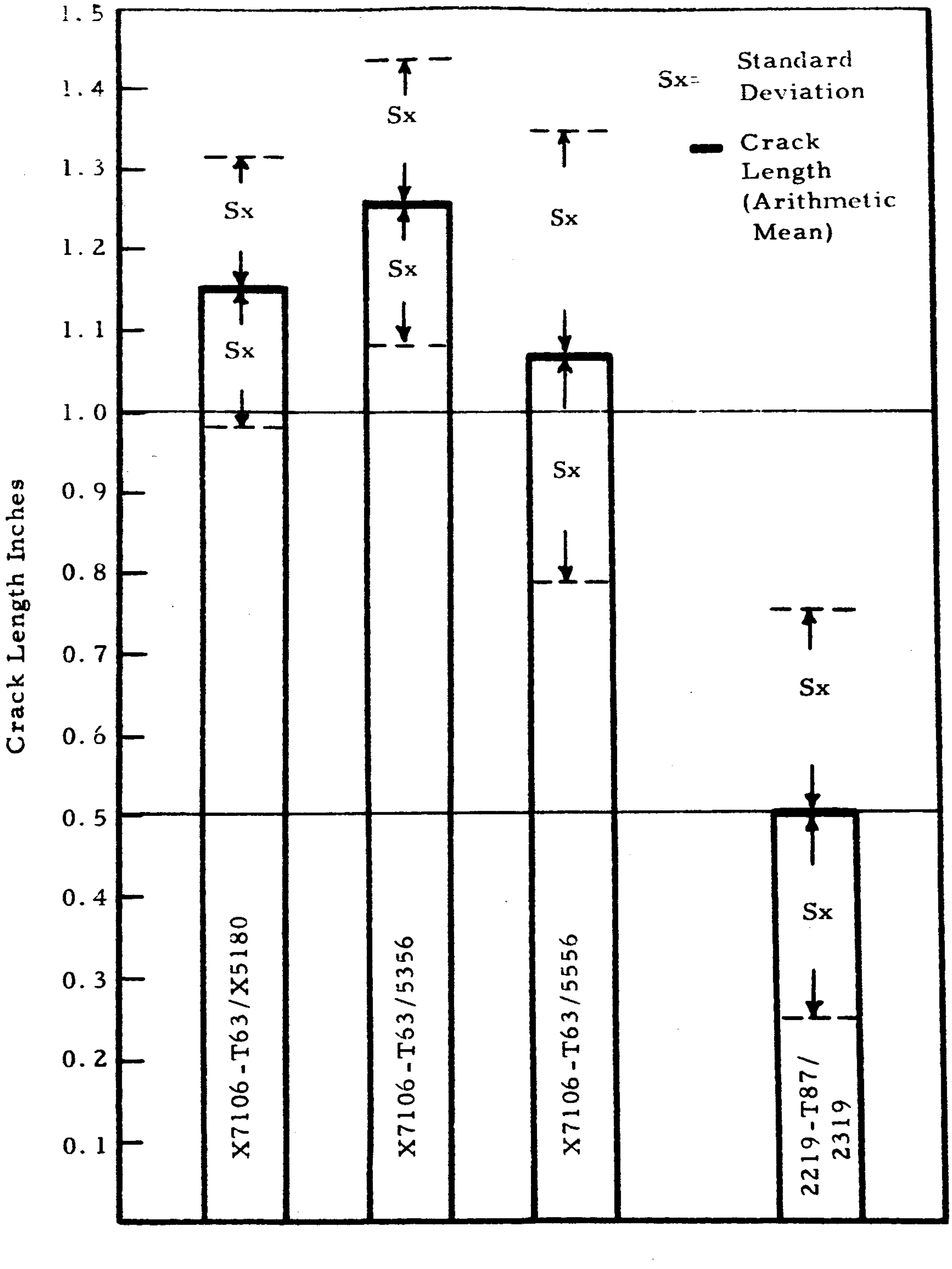
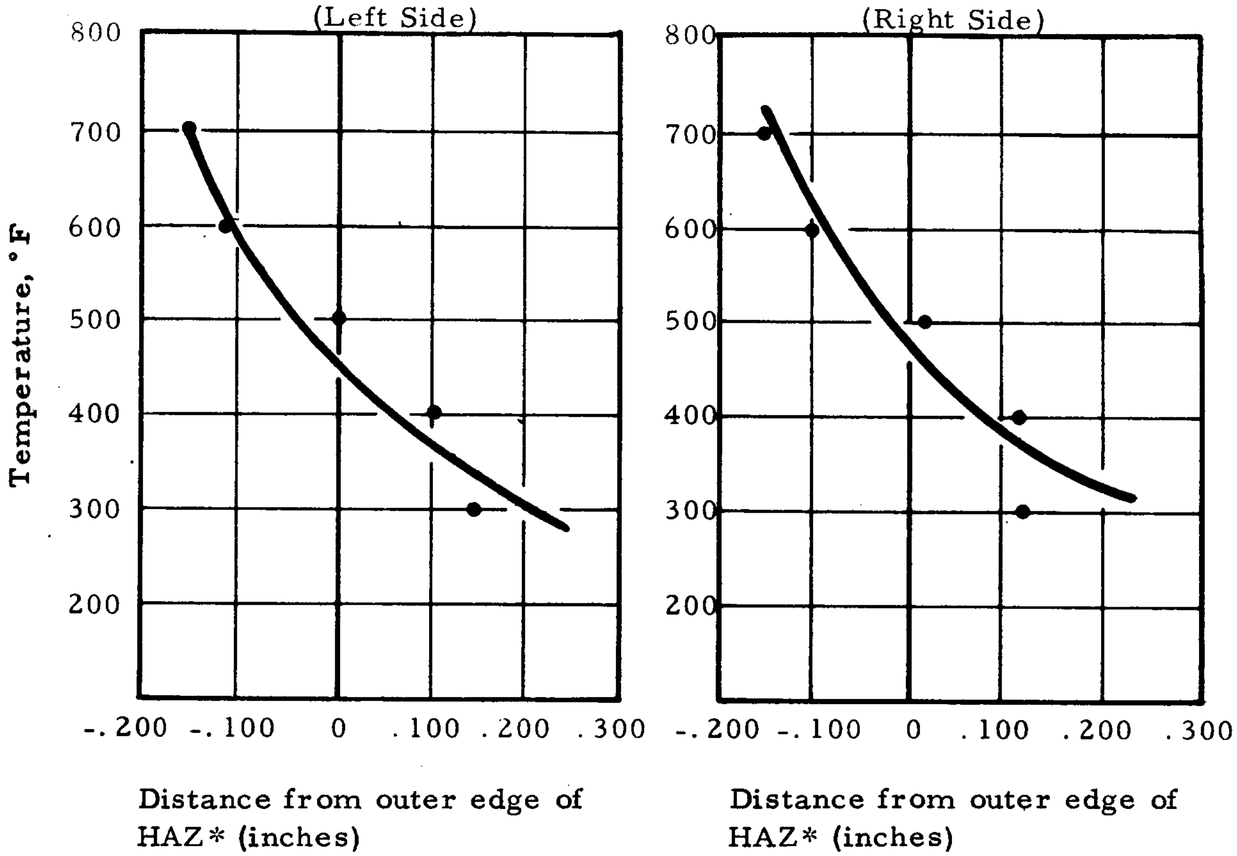


FIGURE 28. GRAPHICAL PRESENTATION OF CRACK DATA OBTAINED FROM HOULDCROFT TESTS



*HAZ: Zone of heat affected base metal revealed by etching.

FIGURE 29. TEMPERATURE DISTRIBUTION IN THE VICINITY OF JOINT IN A TIG WELDED X7106-T63/X5180 PANEL AS REVEALED BY TEMPERATURE SENSITIVE CRAYONS

of the uniaxial and biaxial properties of a number of weldments and further investigations into the weldability of X7106-T63 aluminum alloy. The Appendices A through K of this report constitute the Fifth Annual Summary Report.

1. Evaluation of the Hydraulic Bulge Test

A biaxial and uniaxial test program was set up for 1/8-inch 2219-T87 parent metal and weldments as follows:

(1) Cylinder tests at stress ratios of 1:1, 2:1, and 1:0

(2) Circular hydraulic bulge tests at a 1:1 stress ratio

(3) Elliptical hydraulic bulge tests at a 2:1 stress ratio

(4) LTV biaxial tests at stress ratios of 1:1 and 2:1

(5) MIT biaxial tests at a stress ratio of 2:1

The cylinder tests were used primarily to determine the basic stress-strain relationships for the alloy at three ratios of principal stress. Using the theory of constant elastic strain energy of distortion, as described in Appendix A, the results were compared to uniaxial tensile data on the basis of effective stress and strain. The agreement of these data, as shown in Figure A-3 in Appendix A, indicated that the behavior of the material could be described by the above mentioned theory. The cylinder specimens were adequate for determining strength of weldments but attempts to force failure in the parent metal were unsuccessful.

Once the biaxial stress-strain relationships were established, a strain gage stress analysis of the circular and elliptical hydraulic bulge tests was initiated. The first objective of the program was to determine the applicability to the circular bulge test of the membrane stress equation

$$\sigma = \frac{PR}{2t}$$

and the Timoshenko circular plate equation for large deflections

$$\sigma = KP^{2/3}$$

where

σ = biaxial stress, psi

P = bulge pressure, psi

R = radius of curvature of bulge, inches

t = panel thickness, inches

K = constant depending upon material constants and die geometry

The membrane stress equation was found to hold for parent metal panels, but was unsatisfactory for welded panels once the weld deposit started to yield, as shown in Figure A-9 in Appendix A. The Timoshenko equation, however, using an experimentally determined constant, could be applied to either type of panel up to the yield strength of the parent metal, as Figure A-13 in Appendix A illustrates. The stress-ratio produced in the elliptical bulge test was much lower than expected, so this procedure was eliminated from the program.

LTV biaxial tests were performed at LTV Vought Aeronautic Division, Dallas, Texas. The stress-strain data reported by LTV was converted to effective stress-effective strain and compared to the standard curve. The data fit well, as shown in Figure A-15 in Appendix A. A stress analysis of the MIT biaxial test was performed, but the results were inconclusive since the strain gages failed before the specimen fractured.

2. Evaluation of the Mechanical Properties of Aluminum Alloy Sheet and Weldments Subjected to Uniaxial and Biaxial Stress Fields

The 1:1 circular bulge test was selected to evaluate the biaxial properties since considerable data from such tests were available from the previous work. Thus, the results of the two programs (NAS8-1529 Mod 6 and NAS8-20160) could be combined to form a better statistical basis for analysis. The cylinder burst tests and the LTV and MIT biaxial tests were utilized to establish the validity of the results of the bulge test and to provide a means of calibration.

The test data generated in the fourth and fifth year programs on 2219-T87 and 2014-T6 weldments (no biaxial tests on X7106-T63 welds were performed in the fourth year) were combined and analyzed statistically. The mean values and lower tolerance limits for uniaxial ultimate strength and biaxial strength are tabulated on the following page. The values listed represent the results of from 11 to 15 bulge tests and from 47 to 78 uniaxial tensile tests.

	Uniaxial Ultimate Strength, (ksi)		Biaxial Ultimate Strength, (ksi)		Biaxial/Uniaxial Strength Ratio
	Mean	LTL	Mean	LTL	
TIG 2219-T87/2319	42.7	36.1	43.6	39.1	1.02
MIG 2219-T87/2319	42.8	37.8	44.8	35.9	1.05
TIG 2014-T6/2319	49.9	41.8	48.0	36.2	0.96
TIG 2014-T6/4043	47.9	36.2	44.1	37.3	0.92
MIG 2014-T6/4043	42.9	32.3	39.1	28.2	0.91

Based on the revised method of determining biaxial strength utilizing the formula $\sigma = KP^{2/3}$, the TIG process is superior to the MIG process for 2014-T6/4043 weldments. The mean biaxial strength of the TIG 2014-T6/2319 weldments was higher than the MIG and TIG welds using 4043 filler wire, but the lower tolerance limit was essentially the same as the TIG weld with 4043 filler. The mean biaxial ultimate strength of MIG 2219-T87/2319 weldment was slightly higher than their TIG counterparts, but the TIG welds had the better lower tolerance limit because of the lower degree of scatter of these results.

A brief investigation of the properties of annealed panels and stress-relieved panels was conducted. After annealing, the uniaxial and biaxial weld joint efficiencies were essentially 100 percent based on the strength of the annealed base metal, although the strength levels of both were reduced considerably.

One stress relieving treatment, 525°F for five hours, was employed on all weldments studied. This treatment overaged the parent metal, thus reducing the strength. The strengths of the 2219-T87 and 2014-T6 weldments were affected so slightly by the stress relieving treatment that no definite conclusions could be drawn. The same heat treatment reduced the strength of the X7106-T63 welds to the level of the annealed panels.

3. Weldability of X7106-T63 Aluminum Alloy

One portion of the investigation of the weldability of X7106-T63 aluminum alloy was directed toward establishing the mechanical properties of naturally aged weldments of this alloy fabricated by both the TIG and MIG processes. This portion of the program included weldments in thicknesses of 0.187 inch, 0.50 inch, and 1.00 inch, made with X5180, 5356, and 5556 filler metal alloys. Square butt joints were employed for the 0.187-inch weldments and double V joints were used in the fabrication of the 1.00-inch weldments. Both square butt and double V joints were included in the 0.50-inch TIG weldments. These two joint types were tested in the one thickness in order to establish the effect of dilution on the properties of the joints made with the various filler alloys.

The results of the tensile tests conducted to establish the natural aging characteristics of X7106-T63 weldments are summarized in Tables C-II through C-VII in Appendix C. In each case, significant increases in tensile properties were noted for aging times of 30 days and longer.

The tensile properties of the various X7106-T63 weldments, after an aging period of 12 weeks, are given in Figures C-4, C-5, and C-6. In the case of the 0.187 inch and 0.50-inch weldments, only relatively small differences between MIG and TIG weldments were noted. For the 1.00-inch weldments, the TIG process resulted in ultimate strengths significantly higher than those of the MIG weldments. The X5180 filler wire produced the highest ultimate strengths for both MIG and TIG weldments of 0.187-inch sheet. Within each group of 0.50-inch TIG weldments (TIG square butt and TIG double V), no appreciable differences were noted in the properties of the weldments made with the various filler wire alloys. For the 0.50-inch MIG weldments, lower yield strengths and ultimate strengths were recorded for the weldments made with 5356 filler wire than for those employing X5180 and 5556. Only small differences in ultimate strength were noted between the TIG square butt and TIG double V weldments.

Based on the average ultimate strength, the test results indicate the optimum weldment types among those tested in the three thicknesses to be as follows:

0.187 inch	TIG X5180 and MIG X5180 equivalent
0.50 inch	TIG X5180 square butt
1.00 inch	TIG 5556

A second portion of the investigation was conducted to further investigate the crack susceptibility of X7106-T63 weldments. Modified Houldcroft test specimens, 0.187 inch thick, were employed for this purpose (see Appendix C). Tests were conducted on 2219-T87, 2014-T6, and X7106-T63 weldments. Three filler metal alloys, X5180, 5356, and 5556, were utilized in the tests on X7106-T63 material. Filler alloys 2319 and 4043 were used for the 2219-T87 and 2014-T6 specimens, respectively.

The results, reported as average crack lengths, are summarized in Table C-IX and Figure C-9 in Appendix C. These results indicate that the crack susceptibility of X7106-T63 is comparable to that of 2014-T6, and that each of these alloys exhibits a degree of crack susceptibility significantly higher than that of 2219-T87 alloy.

In addtion to the tests on modified Houldcroft specimens, preliminary cruciform crack susceptibility tests were performed on 0.50-inch X7106-T63 plate. These tests were unsuccessful in that cracks could not be induced with either single-pass or multiple-pass joints. As a result, no further crack susceptibility tests were performed on the 0.50-inch or 1.00-inch material.

APPENDIX A

EVALUATION OF THE METHODS FOR THE DETERMINATION OF THE BIAXIAL STRENGTH OF ALUMINUM ALLOY SHEET AND WELDMENTS (NAS8-20160, PHASE I)

EVALUATION OF THE METHODS FOR THE DETERMINATION OF THE BIAXIAL STRENGTH OF ALUMINUM ALLOY SHEET AND WELDMENTS (NAS8-20160, PHASE I)

A. Introduction

A biaxial and uniaxial test program on 2219-T87 aluminum alloy parent metal and weldments was conducted to evaluate the hydraulic bulge test as a means of measurement of the biaxial mechanical properties of high-strength aluminum alloys. The program was organized as follows:

(1) Circular and elliptical bulge tests and uniaxial tensile tests were performed on a variety of parent metal and weldment specimens. Stress analyses were performed to determine the applicability of the normally used membrane stress equation and the Timoshenko flat plate formula to the calculation of stresses in the circular bulge test.

(2) Cylinder tests simulating thin wall pressure vessels were conducted at three ratios of principal stresses (1:1, 2:1, and 1:0) to determine the biaxial stress-strain relationships needed for the quantitative interpretation of the hydraulic bulge test.

(3) Ling-Temco-Vought (LTV) biaxial tests were conducted on both parent metal and weldments in two stress ratios (2:1 and 1:1) and MIT tests (stress ratio = 2:1) were run on parent metal only.

(4) A comparison of the biaxial results with existing theories of failure (see Appendix D) was made.

This program, therefore, provided data for the direct comparison of several of the principal methods of biaxial testing in use at the present time. The total number of biaxial tests included in the program are summarized in Table A-1.

A description of the experimental procedures used are given in Appendix E. The test material and fabrication data are given in Appendix F.

TABLE A-1. PHASE I BIAXIAL TEST PROGRAM (NAS8-20160)

Type of Test	Material	Specimen Type	Biaxial Ratio	No. of Tests
Bulge	2219-T87	Parent Metal	1:1	3
Bulge	2219-T87/2319	Single Weld	1:1	3
Bulge	2219-T87/2319	Cross Weld	1:1	3
Bulge	2219-T87	Parent Metal	2:1	3
Bulge	2219-T87/2319	Single Weld	2:1	3
Bulge	2219-T87/2319	Cross Weld	2:1	3
Modified Bulge	2219-T87	Reduced Section	1:1	3
Modified Bulge	2219-T87	Reduced Section	2:1	3
Modified Bulge	2219-T87	Single Groove	1:1	3
Modified Bulge	2219-T87	Cross Groove	1:1	3
Modified Bulge	2219-T87	Single Groove	2:1	3
Modified Bulge	2219-T87	Cross Groove	2:1	3
Cylinder	2219-T87/2319	Single Weld	1:1	3
Cylinder	2219-T87/2319	Single Weld	2:1	3
Cylinder	2219-T87/2319	Single Weld	1:0	3
Cylinder	2219-T87	Parent Metal	1:1	3
Cylinder	2219-T87	Parent Metal	2:1	3
LTV Biaxial	2219-T87	Parent Metal	1:1	3
LTV Biaxial	2219-T87/2319	Cross Weld	1:1	3
LTV Biaxial	2219-T87	Parent Metal	2:1	3
LTV Biaxial	2219-T87/2319	Cross Weld	2:1	3
MIT Biaxial	2219-T87	Parent Metal	2:1	3

B. Cylinder Tests

The hydraulic bulge test is excellent for screening materials on the basis of fracture propagation behavior and determining mechanical strength. However, the mechanics of the specimen and test fixture prevent analysis of results in terms of stress. Strains can be measured on these specimens and used to calculate stresses once the relationship is established between strain and stress. In the elastic range, stress is proportional to strain and the stress-strain curve is linear. In the plastic range, however, the relationship must be established for particular materials, especially for those that are anisotropic and strain hardenable. The cylinder loaded by internal pressure and axial loads is one of the few test specimen types for which stress can be calculated and on which strains can be measured to obtain the desired relationship for differing ratios of principal stresses.

Previous investigations have demonstrated that, for many materials, the equations of the theory of constant elastic strain energy of distortion or of the constant octahedral shearing stress can be used to fit the stress-strain relationships for all ratios of principal stresses to a single curve.(5) The cylinder tests were performed to establish the validity of this approach for the materials investigated in this program. The results of the cylinder tests were sufficient to determine the desired stress-strain relationship which enables quantitative interpretation of the hydraulic bulge test results.

The specimen design was determined by the characteristics of the materials, base plate and weldment, and equipment limitations involved. The specimen cross section size was 18-inch diameter made of 0.125-inch thick sheet. The test section length was 23 inches, which was estimated as being sufficient to eliminate end effects at midsection. The specimen was installed in the Universal Testing Machine as shown in Figure A-1 so that tensile or compressive axial loads could be imposed on the specimen simultaneously with internal pressure loading.

The instrumentation, described in Appendix E, provided for the recording of synchronous values of axial load, internal pressure, longitudinal strains, and circumferential strains. These data were tabulated and stress values calculated from the loadings using thin cylinder formulae which provided engineering stress-strain relationships for the loading investigated. The true stress and true strain values were calculated from the engineering values and used to calculate effective stress and effective strain values by the usual formulae

$$\bar{\sigma}_i = \sigma_i (1 + \epsilon_i) \qquad \bar{\epsilon}_i = \ln (1 + \epsilon_i)$$

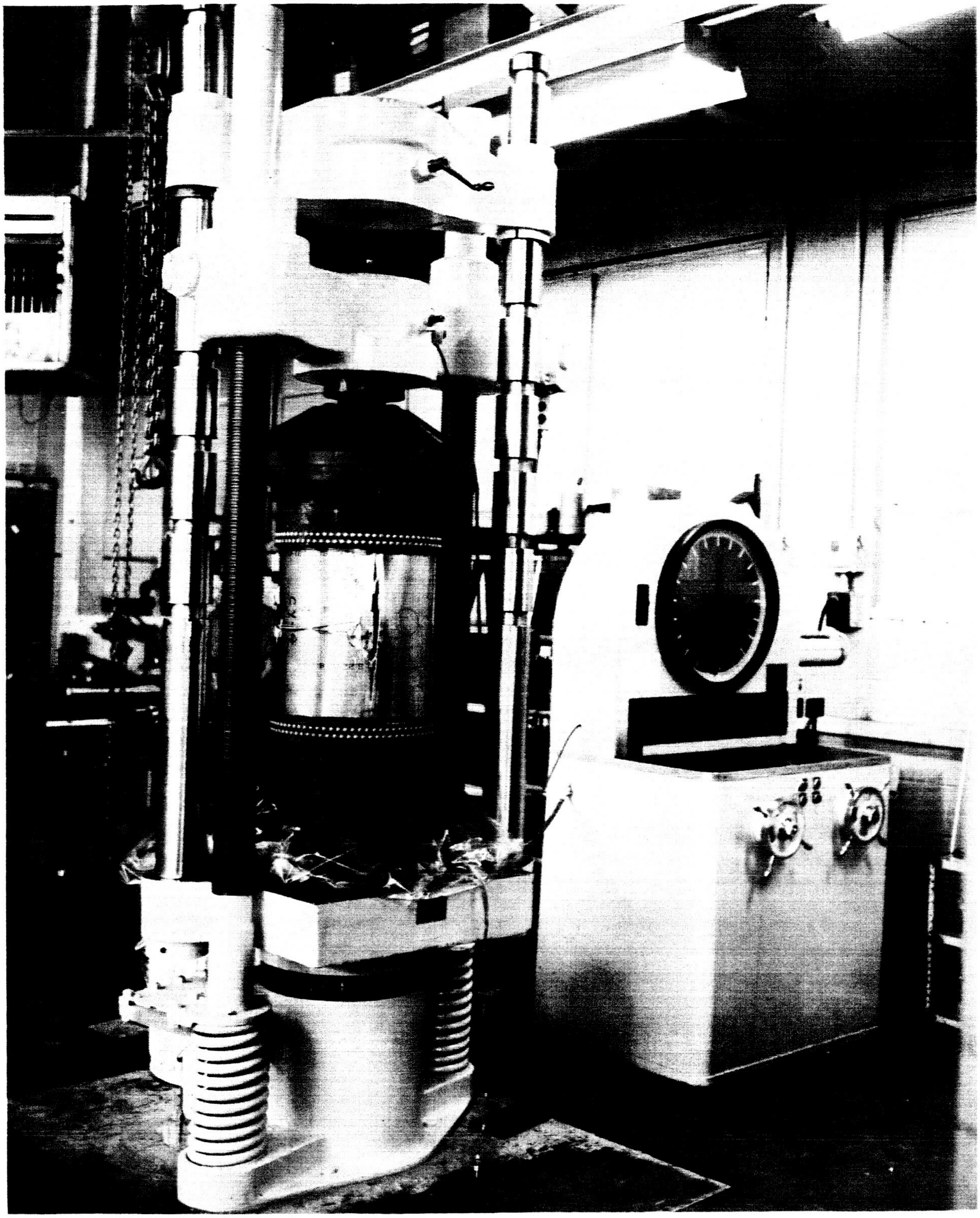


FIGURE A-1. TESTED CYLINDER SPECIMEN IN UNIVERSAL TESTING MACHINE

where

σ = engineering stress

ϵ = engineering strain

$\bar{\sigma}$ = true stress

$\bar{\epsilon}$ = true strain

$$\sigma_e = \frac{1}{\sqrt{2}} \sqrt{(\bar{\sigma}_1 - \bar{\sigma}_2)^2 + (\bar{\sigma}_2 - \bar{\sigma}_3)^2 + (\bar{\sigma}_3 - \bar{\sigma}_1)^2}$$

$$\epsilon_e = \frac{\sqrt{2}}{3} \sqrt{(\bar{\epsilon}_1 - \bar{\epsilon}_2)^2 + (\bar{\epsilon}_2 - \bar{\epsilon}_3)^2 + (\bar{\epsilon}_3 - \bar{\epsilon}_1)^2}$$

where the subscript e denotes effective stress or strain, and the subscript $i = 1, 2,$ or 3; subscripts 1, 2, 3 denote principal stress or strain values.

The development of these equations assumes Poisson's ratio equals 1/2 in the plastic region, but experience has shown that the variation from this value makes little difference in practical results, as this variable approaches the assumed value in plastic flow. The minor principal strain had to be calculated by using Poisson's ratio, and its elastic value was used in the first set of calculations. Trail calculations showed that refinement of results by correcting Poisson's ratio by the secant modulus formula

$$\mu = \frac{1}{2} - \frac{Es}{E}\left(\frac{1}{2} - \nu\right)$$

where

μ = Poisson's ratio

Es = secant modulus

E = elastic modulus

ν = elastic value of Poisson's ratio

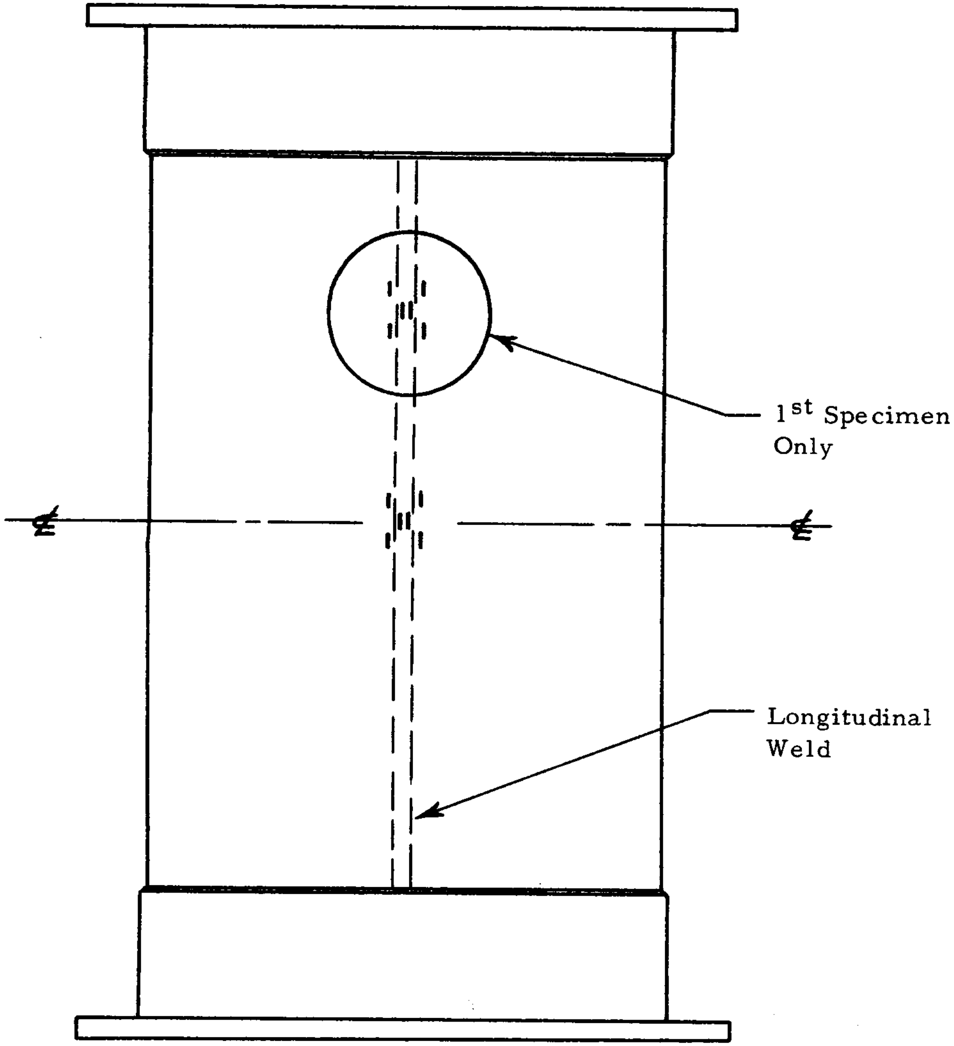
was not justified because the correction was less than experimental error in data obtained. The portion of the experimental error arising from specimen out-of-roundness is greatest in the elastic range because stress redistribution by plastic flow automatically corrects the geometric imperfections in most cases. The majority of this type of error can be corrected graphically by shifting coordinate axes of the stress-strain curves just as one would do when correcting tensile test results of initially bent specimens.

Sixteen cylinder test specimens were fabricated. The first specimen tested was instrumented with strain gages, as shown by Figure A-2, in order to demonstrate that the strains in the specimen midsection were not affected by end restraint. The remainder of the specimens were instrumented only on the central diameter. Strain gages were mounted on the weld metal, both heat-affected zones, and on parent metal 180° from the weld. Uniaxial specimens were also tested in a Universal Testing Machine with data obtained and reduced in the same manner as was used for the cylindrical specimens to compare test results.

After conducting the first test, it was found necessary to stiffen the end plates and improve the seal design to prevent leakage at the fixtures. Joint sealing procedure at the riveted attachment was also improved. Nine specimens were used to determine weldment behavior. On the remaining six specimens, the welds were reinforced in an unsuccessful attempt to obtain failure in the base plate material. The results of the tests are summarized in Table A-2, and the tabular stress-strain data are given in Appendix G.

The curves in Figure A-3 compare the strain data from the 90° rosette on the base plate material at 180° from the weld, with the curve derived from uniaxial tensile tests of base plate material. The data show good fit, presuming initial out-of-roundness to affect the results. Tests 3 and 9, performed at a stress ratio of 1:0, were the only ones with elastic moduli varying significantly from the reference curve. The mean of the results of these two specimens fits the results of Test 10 (also run at a stress ratio of 1:0) which was plotted in Figure A-3. The other deviation from the reference curve is in the "knee" of the curves of those specimens in which the base plate material could be loaded into the plastic range (Tests 11, 12, and 13). This was probably due to the moment induced by the reinforcing plate over the weld while the reinforced section was still in the elastic range and before stress redistribution by plastic flow(6). The set of results justified the procedure investigated and provides a sound basis for transforming strain data from the bulge tests to stress values.

The comparison of the results derived from the rosettes on the heat-affected zones, for Tests 2 through 10, displayed considerably more scatter. Typical curves are shown in Figure A-4. The elastic moduli fit the base plate curve well, but the scatterband increased with plastic strain. It was, of course, difficult to place strain gages on this zone precisely, and there are



Gage No.	Direction	Location
1 & 9	Circumferential	Left HAZ
2 & 10	Longitudinal	Left HAZ
3 & 11	Circumferential	Weld Bead
4 & 12	Longitudinal	Weld Bead
5 & 13	Circumferential	Right HAZ
6 & 14	Longitudinal	Right HAZ
7 & 15	Circumferential	Parent Metal 18° from Weld
8 & 16	Longitudinal	Parent Metal 180° from Weld

FIGURE A-2. SCHEMATIC OF STRAIN GAGE LOCATIONS ON CYLINDER TEST SPECIMENS

TABLE A-2. SUMMARY OF CYLINDER TEST RESULTS

Test No.	Cylinder No.	Type Loading	Burst Pressure (psi)
1	XCY-1	2:1	(a)
2	CY-1	2:1	572
3	CY-4	1:0	570
4	CY-5	1:1	575
5	CY-2	2:1	572
6	CY-10	2:1	575
7	CY-11	1:1	540
8	CY-12	1:1	542
9	CY-13	1:0	575
10	CY-16	1:0	575
11	CY-14	2:1	1010(b)
12	CY-9	2:1	995(c)
13	CY-15	2:1	1010(c)
14	CY-7	1:1	450(d)
14-A	CY-7	1:1	640(e)

(a) Weld crowns ground off
(b) Longitudinal weld reinforced; parent metal failure
(c) Longitudinal weld reinforced; patch blew off
(d) Longitudinal weld reinforced; stopped because of excessive leaks
(e) Longitudinal weld reinforced; end rivets failed

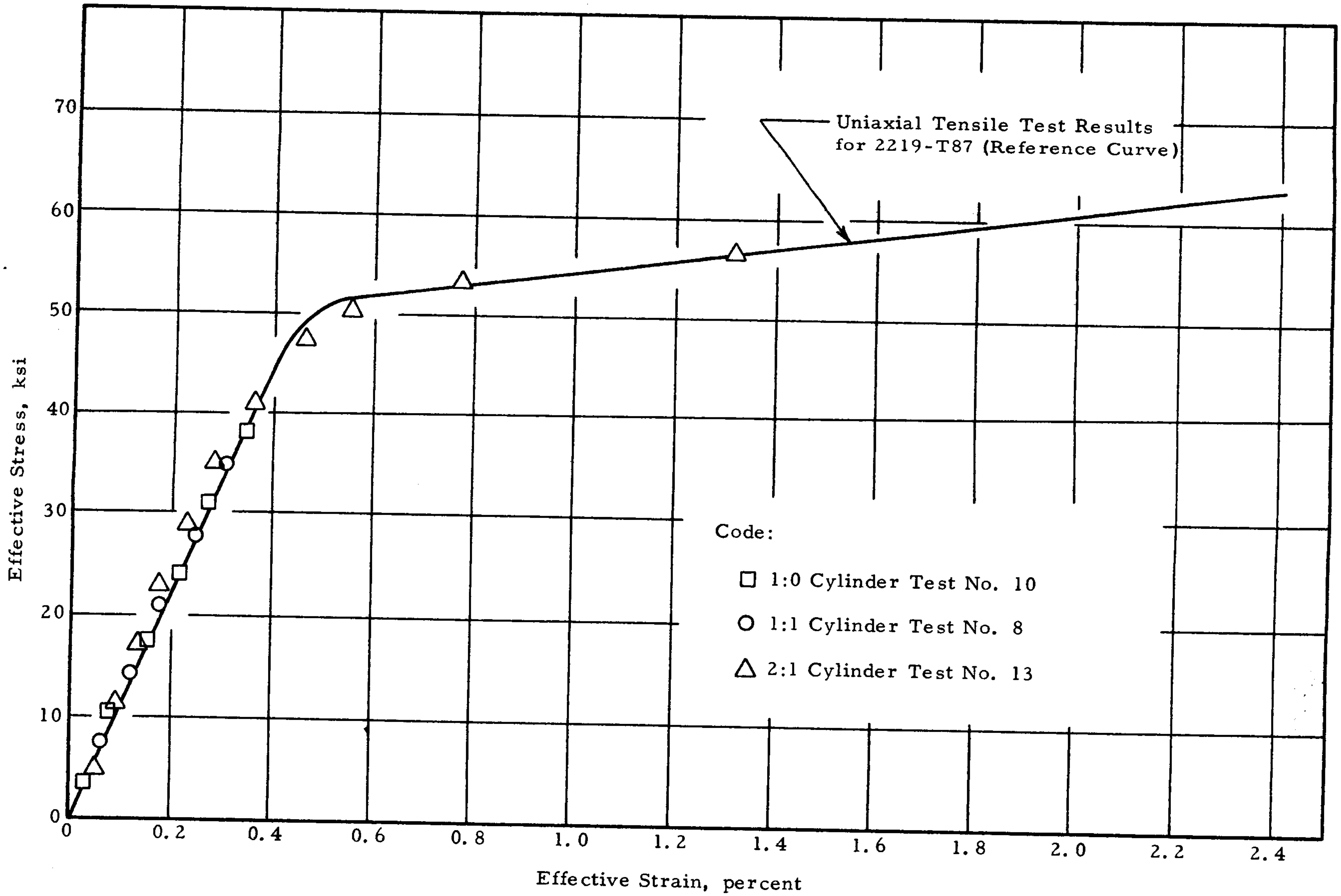


FIGURE A-3. BIAXIAL AND UNIAXIAL PARENT METAL DATA CONVERTED TO EFFECTIVE STRESS AND STRAIN

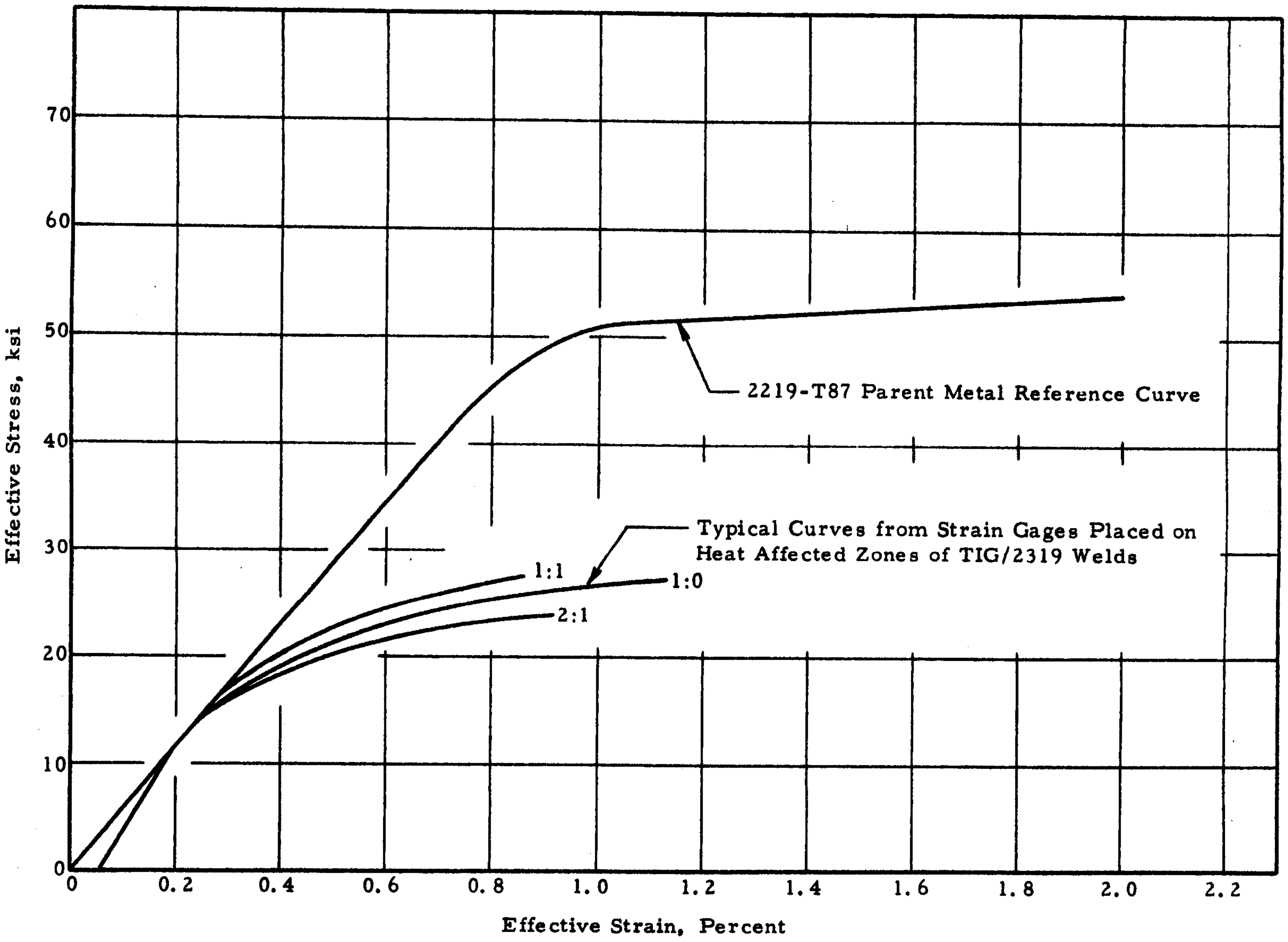


FIGURE A-4. BIAXIAL AND UNIAXIAL HAZ DATA CONVERTED TO EFFECTIVE STRESS AND STRAIN so many variables involved that one cannot associate cause with effect in analyzing these data. Test 1 results were quite different from those of Tests 2 through 10, possibly because of the preloading used to check out fixtures and test procedures.

The rosettes on the weld metal gave very erratic results. Characteristic curves are given in Figure A-5. Obviously, the mechanics of loading and geometry of this part of the structure is the most complex and liable to deviate from the ideal assumed in stress calculations for the cylinder. The resulting stress-strain curves do show characteristic dependence on state of stress, however. This dependence most likely results from the mechanism of loading the material rather than from materials properties.

In all cases, failure in the cylindrical specimens occurred at the fusion line in the same fashion as was observed in the bulge panels. The typical appearance of the fractures in the cylinders is shown in Figure A-1. It may be noted that the failure pressure was not affected by state of stress to the degree or in the direction that would be predicted by the theory of failure that corresponds to the relationship which correlates flow behavior of the base plate material. The failure behavior of base plate material could not be determined in this program because of specimen design limitations; however, the results do provide a method of determining stress magnitudes in bulge tests by measuring strains in base plate material as a function of stress.

C. Stress Analysis of the Circular Hydraulic Bulge Test

The membrane stress equation has been suggested(7) for calculating the stresses in the hydraulic bulge test panel

$$\sigma_{mem} = \frac{PR}{2t}$$

where

P = pressure, psi

R = radius of curvature, inches (calculated from bulge height and die geometry)

t = panel thickness, inches

The membrane stress in a circular flat plate clamped at the edge is also given by Timoshenko(8) as:

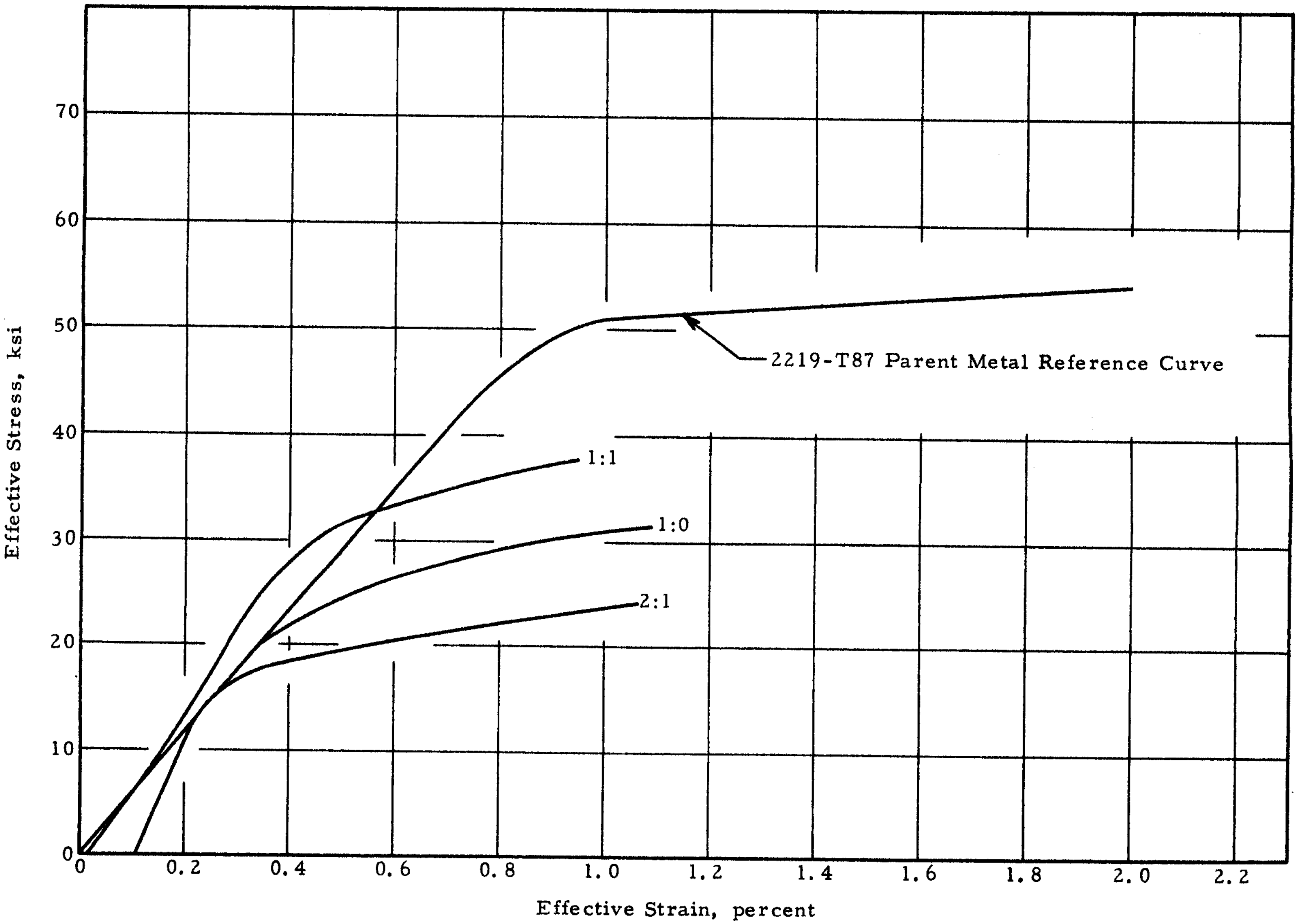


FIGURE A-5. BIAXIAL AND UNIAXIAL WELD BEAD DATA CONVERTED TO EFFECTIVE STRESS AND STRAIN

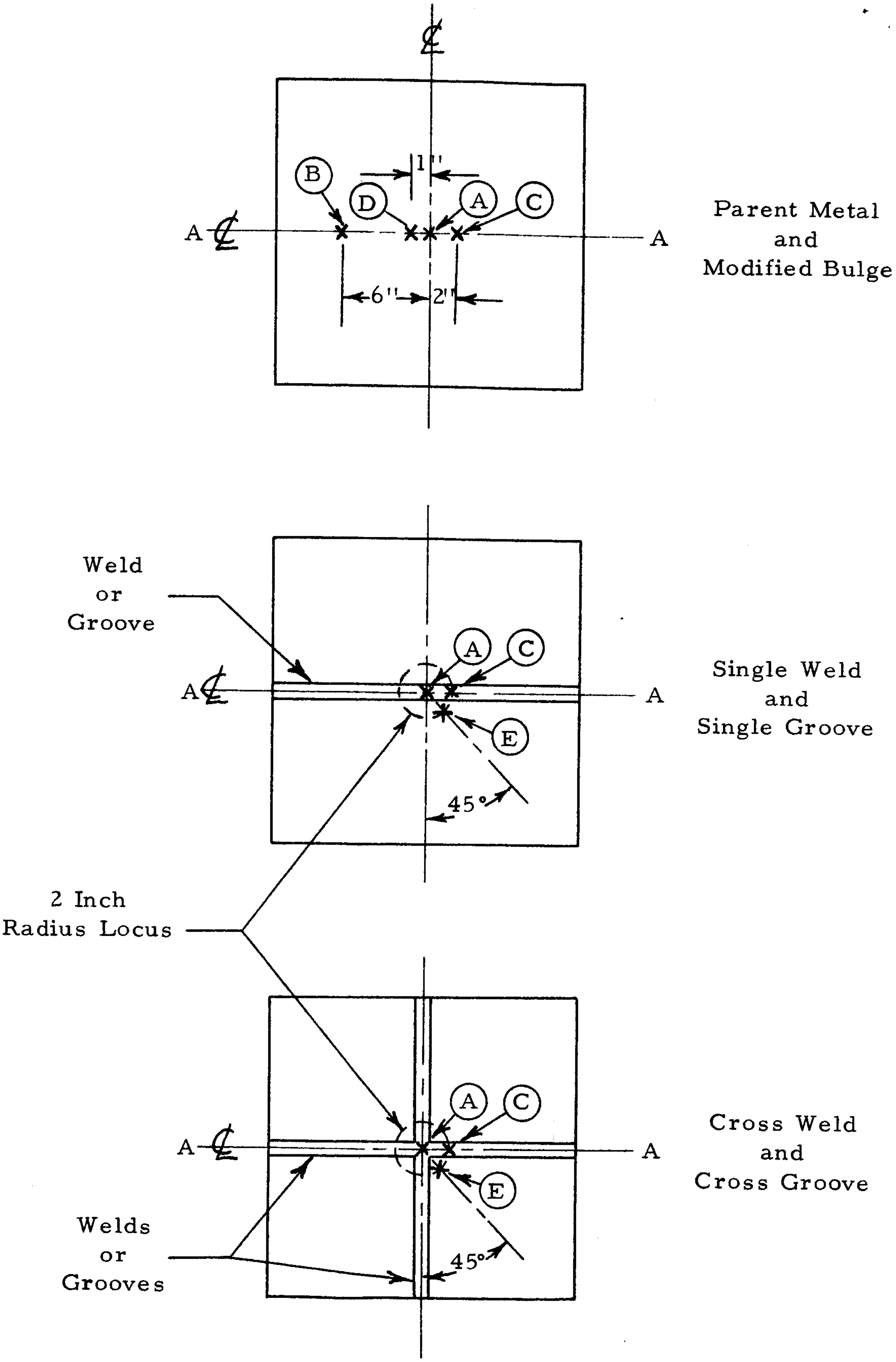


FIGURE A-6. SCHEMATIC OF STRAIN GAGE LOCATIONS ON 1:1 BULGE TEST PANELS

$$\sigma = 0.423 \left(\frac{EP^2a^2}{h^2}\right)^{1/3} = KP^{2/3}$$

where

E = modulus of elasticity = 10.5×10^6 psi

P = pressure, psi

a = radius of circular plate = 9 inches

h = thickness of plate = 0.125 inch

σ = biaxial stress in panel, psi

The stresses produced in the circular hydraulic bulge test were measured at low bulge heights by correlating hydraulic bulge test strain data with the cylinder test stress-strain curves described in the previous section, so that the applicability of these equations could be studied.

All of the bulge test panels listed in Table A-1 were instrumented with electric resistance-type strain gages on the parent metal, and the weld metal when appropriate. Typical locations of these strain gages for the 1:1 hydraulic bulge tests are shown schematically in Figure A-6. The pressure, bulge height and strain data are given in Appendix G. The strain measured at a point two inches from center was essentially the same as that measured at the center. Since the approach to the problem was to monitor parent metal strain versus pressure on all tests, the center position could not be used on panels with welds through the center. Therefore, the two-inch-from-center position was selected for the reference strain gage.

The first objective of this program was to determine the stress ratio produced in a circular bulge test panel. For an isotropic material, a 1:1 stress state should produce a 1:1 strain state on that plane. Examination of the data from the three-element 120° rosette strain gages mounted on the parent metal showed that, in general, a strain state very close to 1:1 was obtained. To determine the ratio of principal stresses in a specimen, the stress state was calculated for the highest elastic strain condition at the two-inch position on the panel. The principal strains were calculated by constructing Mohr's circle, Figure A-7. After correcting for bending (discussed in a later paragraph), the principal strains were converted to principal stresses in the usual way for an isotropic material by:

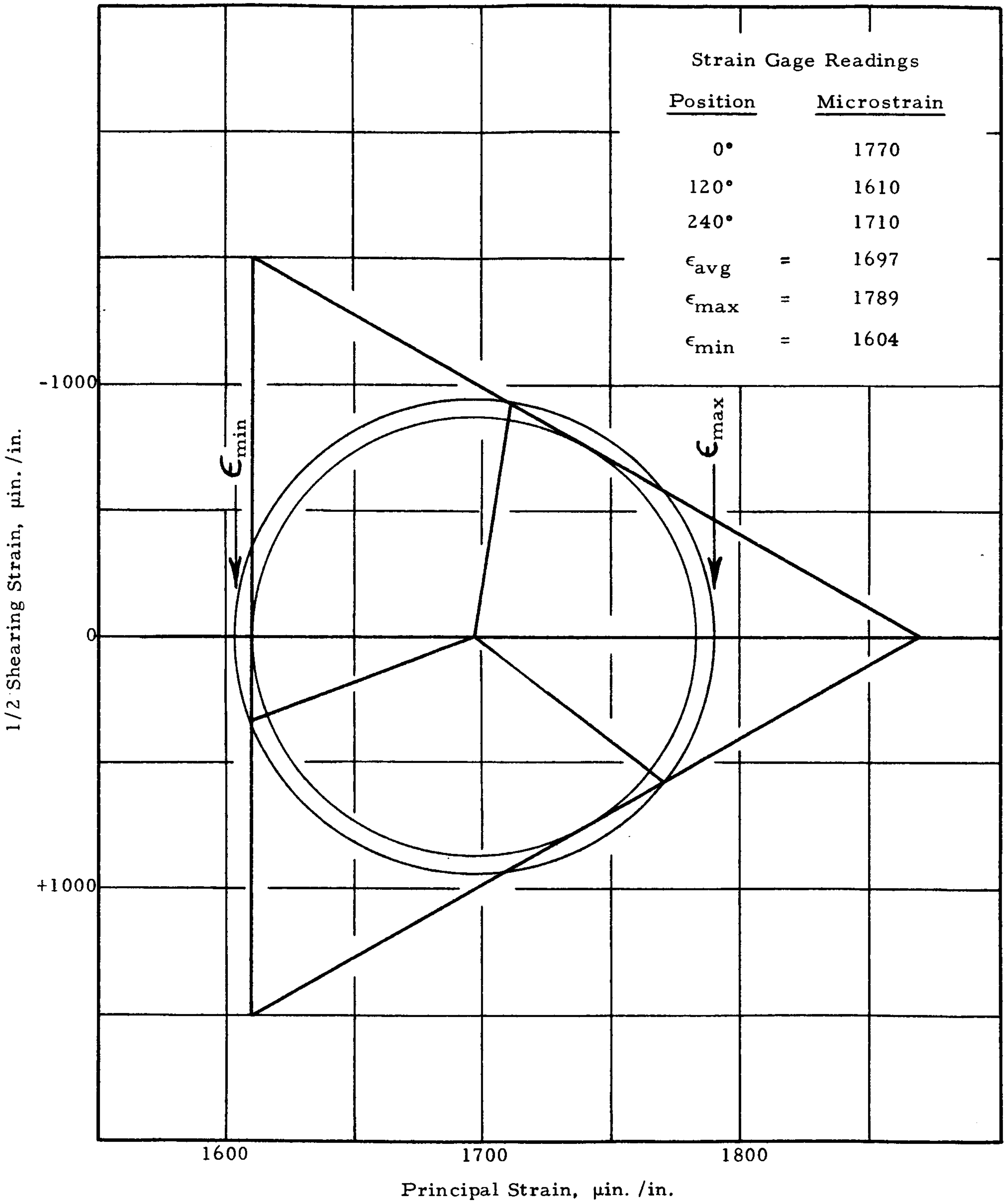


FIGURE A-7. MOHR'S CIRCLE FOR 1:1 BULGE TEST PANEL A-1 AT P = 40 PSI

$$\sigma_{max} = \frac{(\epsilon_{max} + \mu\epsilon_{min})E}{1 - \mu^2}$$

$$\sigma_{min} = \frac{(\epsilon_{min} + \mu\epsilon_{max})E}{1 - \mu^2}$$

where

E = modulus of elasticity = 10.5×10^6 psi

μ = Poisson's ratio = 0.29

ϵ_{max} = maximum principal strain

ϵ_{min} = minimum principal strain

σ_{max} = maximum principal stress

σ_{min} = minimum principal stress

The results of this analysis are given in Table A-3. The values of the stress ratios varied from 1.01 for specimen A-7 to 1.22 for specimen AT1-9. In general, the welded panels produced a more unbalanced stress strain state than the parent metal and grooved parent metal panels. The reason for this is not clear, but may be related to the stiffening effect of the weld bead before it reaches its yield stress. The direction of maximum principal stress, Table A-2, is approximately normal to the weld in the single weld panels and normal to one of the two welds in the cross-weld panels. In the machined groove panels, the direction of maximum prinicpal stress does not show a definite trend.

As discussed previously in the section on cylinder tests, the effective stress-effective strain reference curve and associated equations provide a means for determining the stress-strain relationship for any desired state of stress. The curve in Figure A-8 was derived in this manner for a 1:1 stress ratio.

Pressure, bulge height and strain had been measured at discreet intervals throughout each bulge test so that the membrane stress (PR/2t) could be calculated and compared to the stress determined from the strain data and Figure A-8. The result of this comparison is shown in Figure A-9. This graph illustrates the validity of the membrane stress equation for parent metal panels. It also shows that (for this particular combination of material,

TABLE A-3. PRINCIPAL STRESSES IN 1:1 HYDRAULIC BULGE TEST PANELS BELOW YIELD STRESS

Panel Description			Test	Principal Stresses			
Material & Process	Type	No.	Pressure (psi)	Max (psi)	Min (psi)	Ratio	Direction(a)
2219-T87 Parent Metal	Parent	A1	40	19,900	18,400	1.08	19°
		A27	-	(b)	-	-	-
		A28	-	(b)	-	-	-
	Reduced Section Parent	A7	(b)	22,700	22,400	1.01	0°
		A8	40	22,000	21,100	1.04	30°
		A9	33	18,000	16,200	1.11	11°
		A25	39	16,800	16,000	1.05	80°
	Single Groove Parent	A13	-	(b)	-	-	-
		A14	46	23,500	22,800	1.03	30°
		A15	32	19,400	18,900	1.03	27°
	Cross Groove Parent	A16	41	19,200	18,700	1.03	75°
		A17	48	24,700	21,600	1.14	45°
		A18	44	23,700	21,600	1.10	90°
TIG 2219-T87 2319	Single Weld	AT1-2	40	21,600	18,500	1.17	85°
		AT1-3	50	22,300	20,700	1.08	80°
		AT1-7	41	21,600	19,600	1.10	90°
	Cross Weld	AT1-1	45	19,100	18,300	1.04	3°
		AT1-8	42	20,900	17,700	1.18	5°
		AT1-9	48	22,400	18,400	1.22	88°

(a) Angle of maximum principal stress to reference axis (through center of panel and parallel to one panel edge).

(b) Data not obtained.

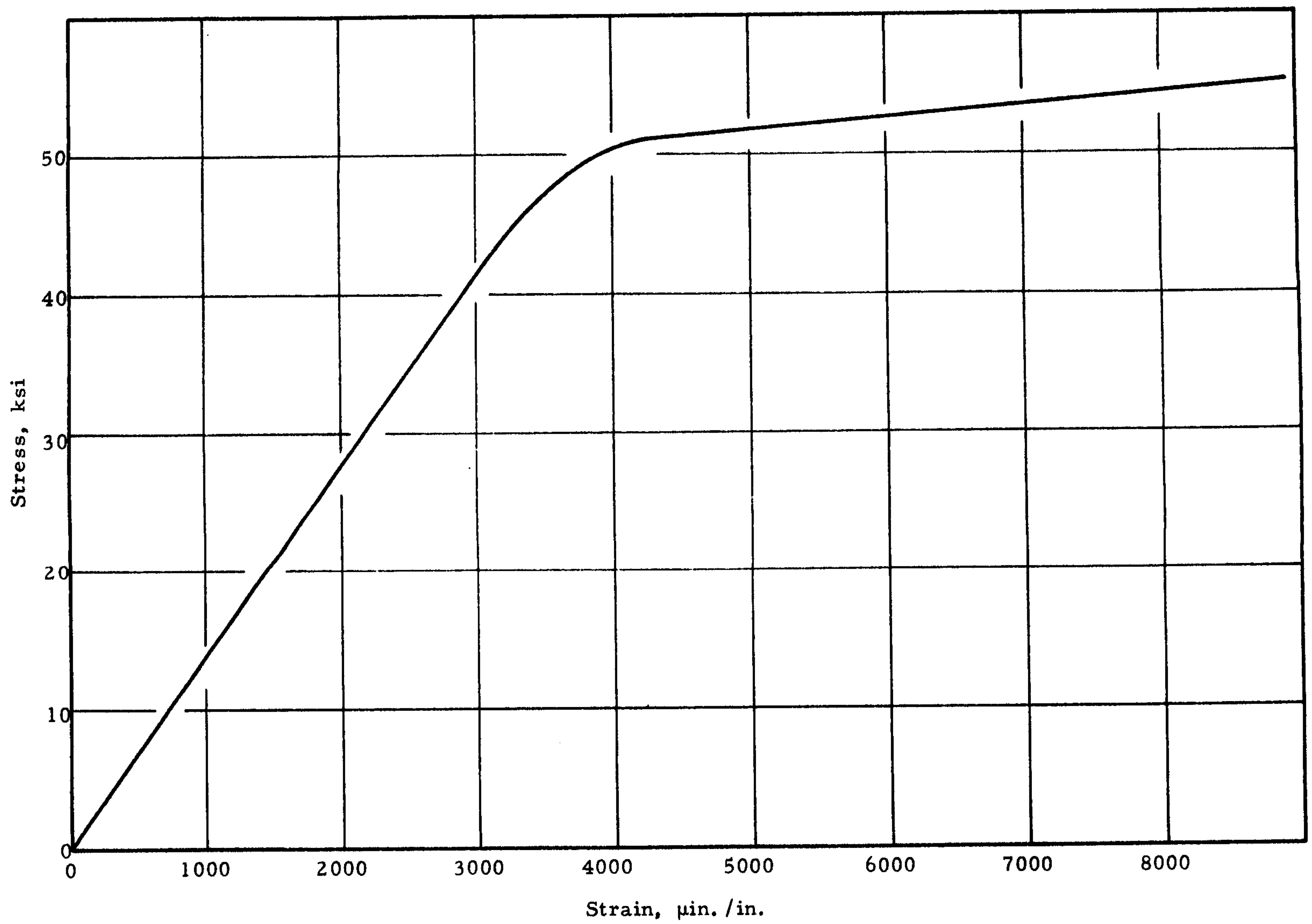


FIGURE A-8. STRESS-STRAIN CURVE FOR 2219-T87 ALUMINUM ALLOY SUBJECTED TO A 1:1 STRESS STATE (Derived from Reference Curve in Fig. A-3)

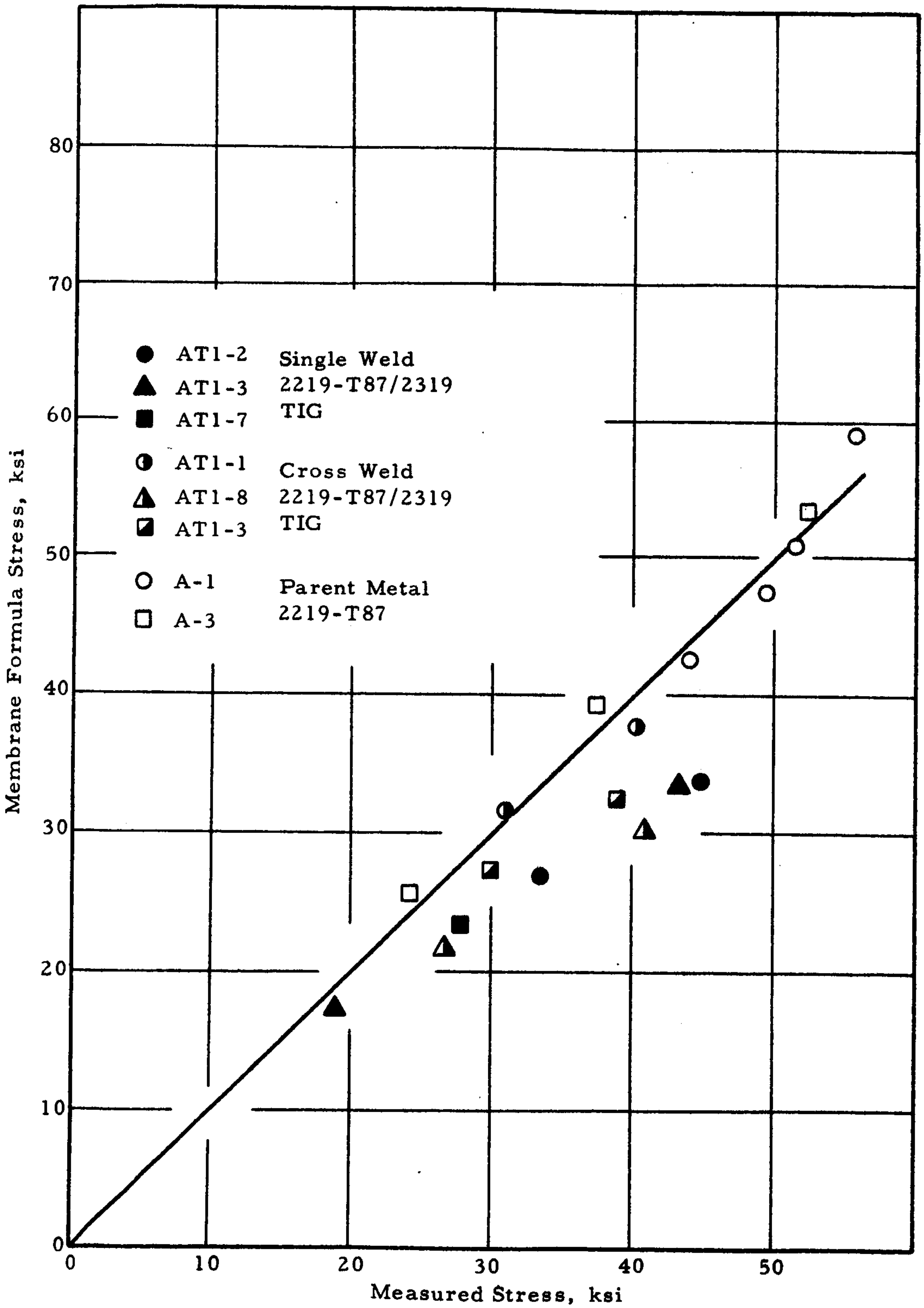


FIGURE A-9. COMPARISON OF MEMBRANE FORMULA STRESSES WITH MEASURED STRESSES. (Membrane Formula Stresses Calculated from $\sigma = PR/2t$. Measured Stresses Determined Experimentally with Strain Gages.)

material thickness, and die geometry at least) that the membrane stress equation gives stress values as much as 25% lower when applied to welded panels.

As discussed earlier, Timoshenko's formula for stress for large deflections of a circular plate clamped at the edge predicts that this stress will be proportional to the two-thirds power of the applied pressure. In Figure A-10, the parent metal strain two inches from center is shown to be a smooth function of this parameter. Where two-element or three-element gages were used, the average strain at that point was computed to construct this curve since the direction of maximum principal strain varied considerably within this group of tests.

Since the radius of curvature of the test panel decreases continuously during the bulge test, an increasing amount of bending strain is experienced by the panel as it is pressurized. Two tests were run to determine the amount of bending strain as a function of bulge height for parent metal panels. The results of these two tests are given in Figure A-11.

As long as a panel is uniform in cross-section and properties, the curve in Figure A-11 is applicable. However, panels containing low strength welds or grooves follow the relationship in Figure A-11 only until yielding occurs in the outer fibers of the weld or groove. If the material were ideally elastic-plastic, the bending moment and the corresponding bending strain would not increase beyond the value at which yielding occurred. Actual experience has shown(9) that, for a rectangular section, the stress at which a material has become fully plastic in bending is 1.5 times the stress which produced initial yielding in the outer fibers. This means that it can carry 1.5 times the bending moment that was sufficient to initiate yielding. These procedures also do not take into account the effect of strain hardening. Since the strain hardening coefficients of the 2219 and 2319 alloys are small (approximately 0.1), the effect of strain hardening on the bending moment was not considered in this analysis.

Using this criteria, the bulge panel strain data were corrected for bending strain. The adjusted data (Fig. A-12) show a linear relationship between strain and the two-thirds power of the applied pressure for welded panels, panels with machined grooves, and parent metal panels.

The bulge panel stress for welded panels determined from the strain data and Figure A-11 is plotted versus (P)2/3 in Figure A-13. Also included in this figure is the parent metal membrane stress (PR/2t) data (average of six tests). The curve is linear in the elastic strain region as predicted by the Timoshenko formula. However, the slope of the curve is less than that

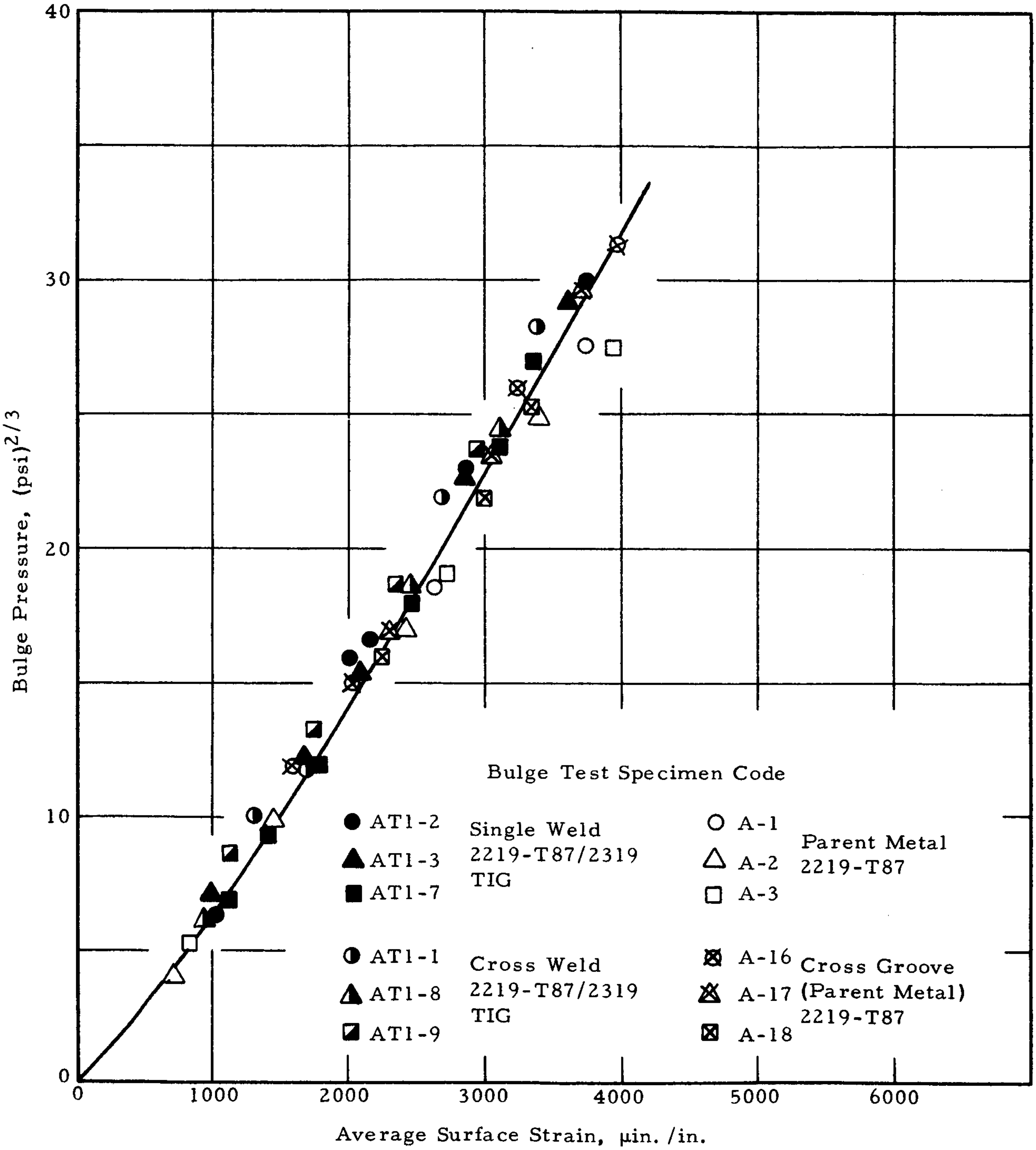


FIGURE A-10. STRAIN-PRESSURE DATA FROM CIRCULAR HYDRAULIC BULGE TESTS

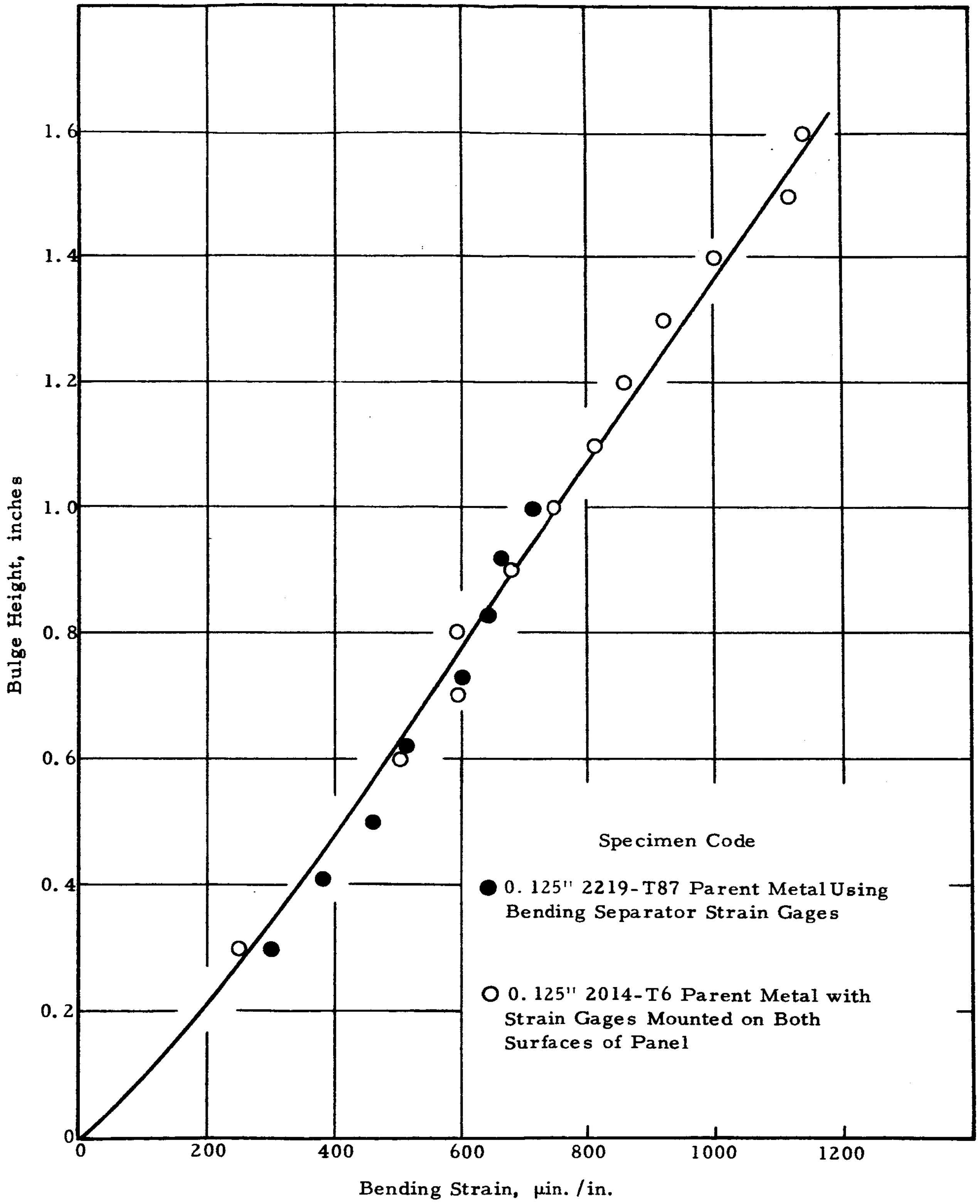


FIGURE A-11. BENDING STRAIN AS A FUNCTION OF BULGE HEIGHT IN THE CIRCULAR HYDRAULIC BULGE TEST

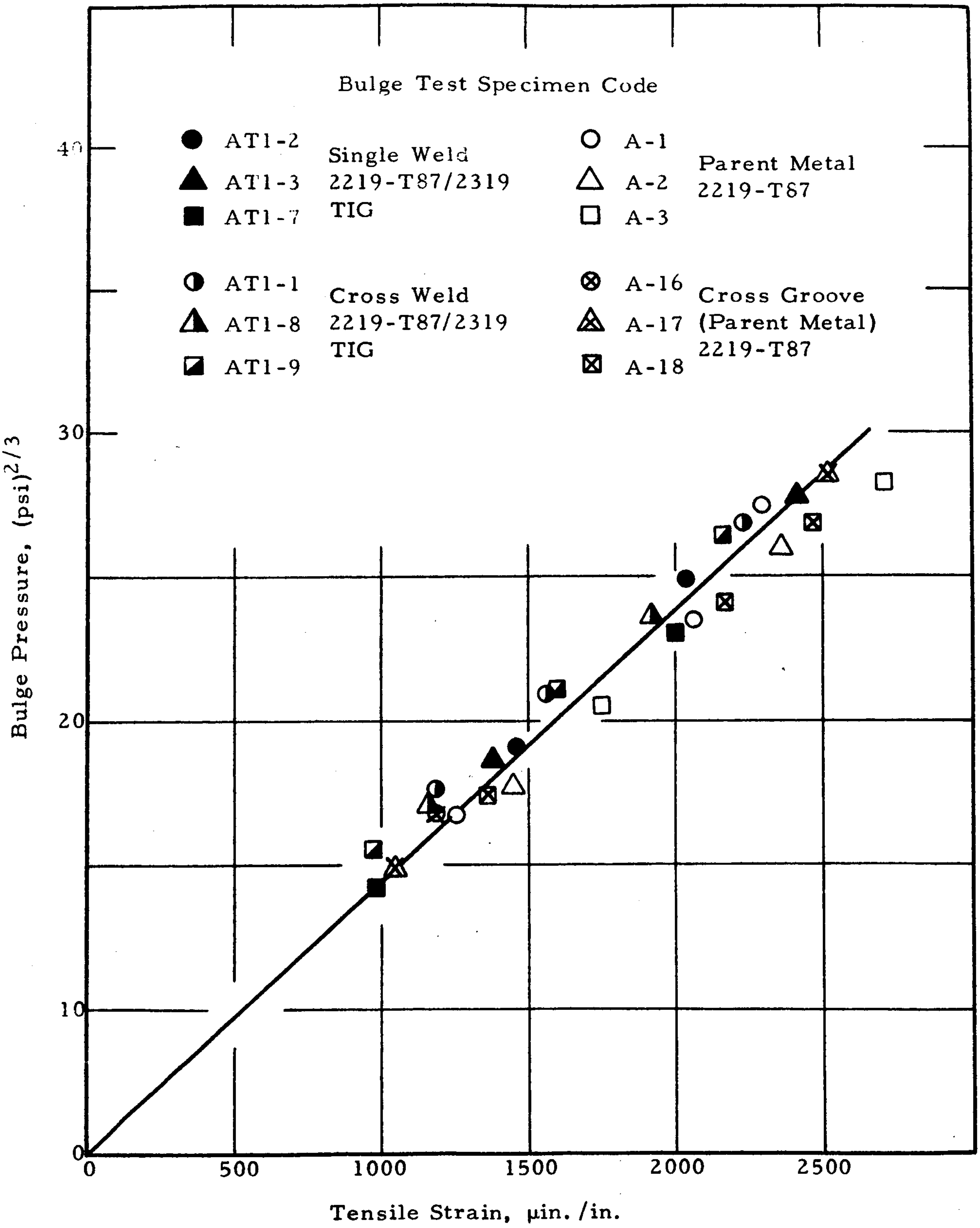


FIGURE A-12. ADJUSTED STRAIN-PRESSURE DATA FROM CIRCULAR HYDRAULIC BULGE TESTS

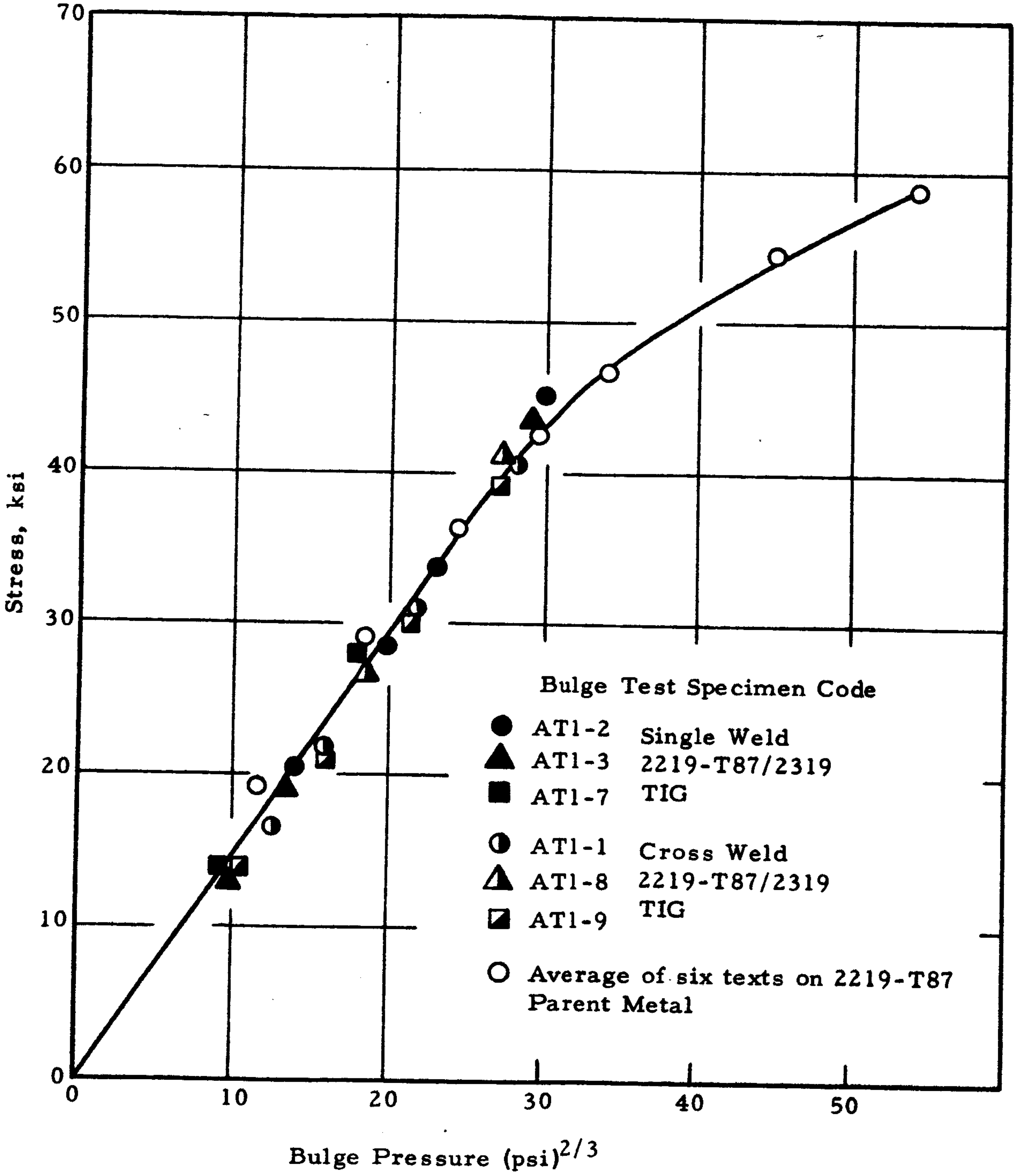


FIGURE A-13. RELATIONSHIP BETWEEN STRESS AND PRESSURE FOR 1:1 BULGE PANEL predicted by the elastic constants and the die geometry. This may be a result of not achieving the ideal boundary conditions of a perfectly clamped edge assumed in the derivation of the formula.

It appears, however, that the stress versus (P)2/3 curve can be established with parent metal bulge tests, using the membrane stress (PR/2t) equation. Then, the ultimate strength of welded panels can be obtained from this curve and the pressure necessary to fail the panel.

D. Stress Analysis of the Elliptical Bulge Test

All of the elliptical bulge test panels listed in Table A-1 were instrumented with electric resistance strain gages on both the parent metal and on the weld metal. The pressure, bulge height and strain data are given in Appendix G. The strain uniformity in the vicinity of the panel center was determined, and it was established that a position two inches from the center of the panel could be used for the reference strain gage.

The stress ratio obtained in the elastic range was calculated from the standard formulas previously described in the analysis of the circular bulge test. The principal strains were measured as a function of pressure and bulge height. Before calculating membrane stresses, the strain data was corrected by subtracting that portion attributed to the bending of the panel.

The bending strain versus bulge height was determined with bending separator strain gages or by strain gages mounted on a concave as well as the convex side of a parent metal panel. The results are given in Figure A-14.

Three 2219-T87 parent metal panels were instrumented with strain gages. The principal strains were calculated and were found to be in the direction of the two axes of the ellipse, with the maximum strain across the short dimension. At a bulge height of 0.5 inch, the stress ratios were found to vary from 1.23:1 to 1.27:1 for the three panels.

Not only was the stress ratio lower than desired, it did not remain constant throughout the duration of the test. It decreased from its value of approximately 1.25:1 in the elastic region towards a value of 1:1 at stress levels producing plastic strains of approximately one percent.

One additional parent metal test was conducted without using the bolts normally used to hold the die halves together. This was done to determine whether or not a change in the restraint would have a beneficial effect on the stress ratio. Specimen A-29 (2219-T87 parent metal) was bulged while the die was held together in a Baldwin Universal Testing Machine. The test had

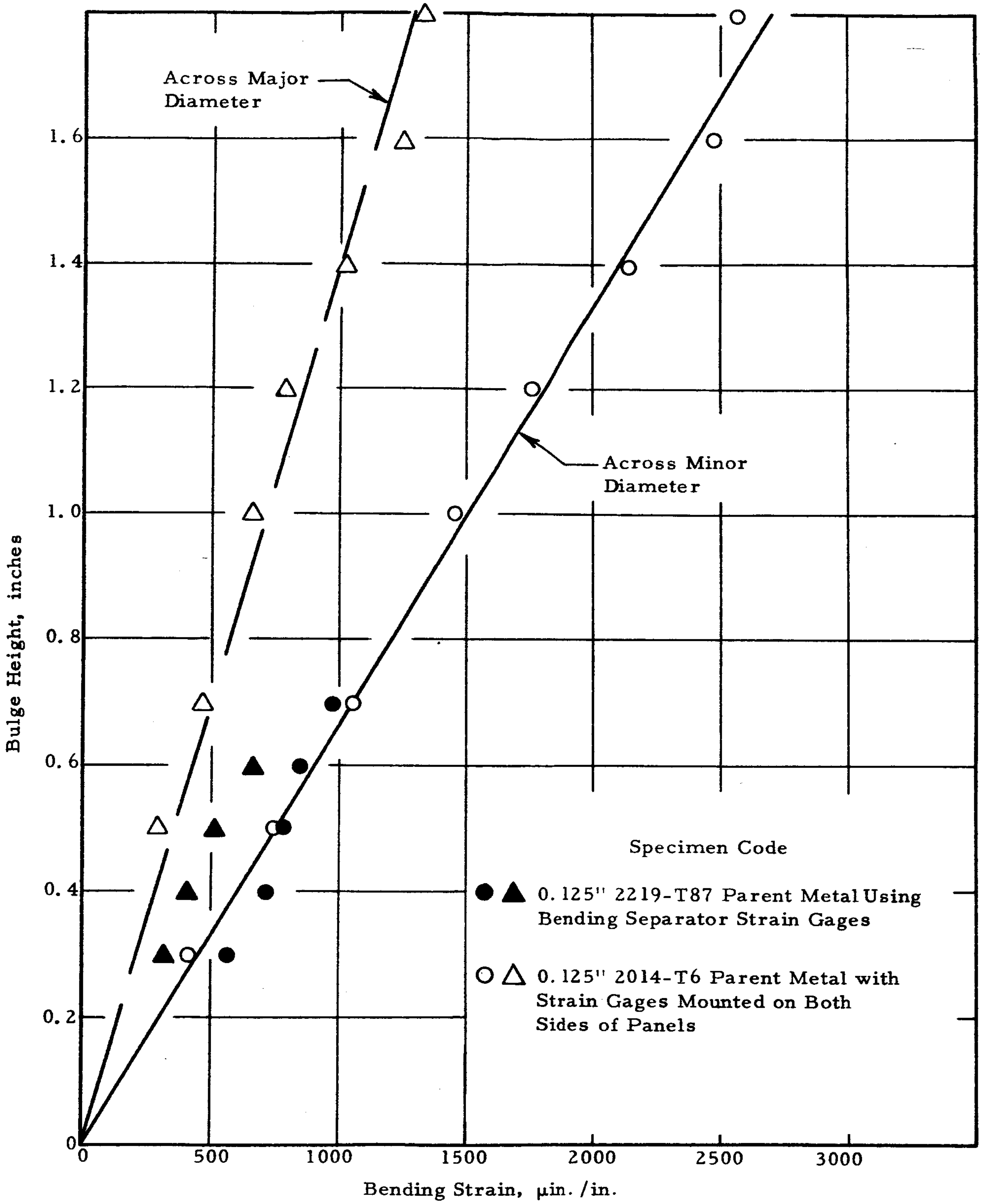


FIGURE A-14. BENDING STRAIN AS A FUNCTION OF BULGE HEIGHT IN THE ELLIPTICAL BULGE TEST to be discontinued after reaching a bulge pressure of 280 psi because the capacity of the machine was insufficient to prevent leakage beyond this point. At a bulge height of 0.8 inch, the maximum and minimum principal stresses were 22,900 psi and 16,100 psi, respectively. This represents a stress ratio of 1.42:1, which is higher than that obtained when the die halves and specimen were bolted together. More important, however, was the indication that the stress ratio remained relatively constant and plastic strain was observed in the high stress direction only. This more closely approaches the strain behavior characteristic of cylinders in a 2:1 stress state. Based on the preceding test result, it appears that elimination of the hold down bolts would improve the performance of the elliptical bulge test. This would require a substitute method for holding the die halves together during a test.

The analysis of the data on the remainder of the elliptical bulge tests, as discussed above, showed that a 2:1 stress state was not achieved in any of the tests.

E. Ling Temco Vought Biaxial Tests

These tests were conducted at LTV Vought Aeronautics Division, Dallas, Texas, on a subcontract basis. Their report on this work is presented in Appendix H. Both parent metal and welded specimens were tested in a 1:1 and 2:1 stress field. Data from the parent metal stress-strain curves were converted to effective stress and effective strain. These data are compared to the reference curve in Figure A-15. A good fit was obtained, which indicates again that the stress-strain behavior of this alloy can be described by the theory of constant elastic strain energy of distortion.

F. MIT Biaxial Tests

These tests were run on 2219-T87 parent metal only. One specimen was instrumented with strain gages (longitudinal and transverse) in the reduced section. The stress-strain data given in Appendix G are plotted in Figure A-16. The stress ratio, as a function of longitudinal strain, is presented in Figure A-17. Below the elastic limit, a stress ratio of the order of 6:1 was measured. As the test section became plastic, the stress ratio began to decrease. The stress ratio in the plastic region was calculated from the effective stress-effective strain curve developed previously. At 66,500 psi, the limit of the strain gages was reached. The stress ratio at this point was higher than the desired value of 2:1. It is not known if a 2:1 state was achieved prior to failure of the specimen.

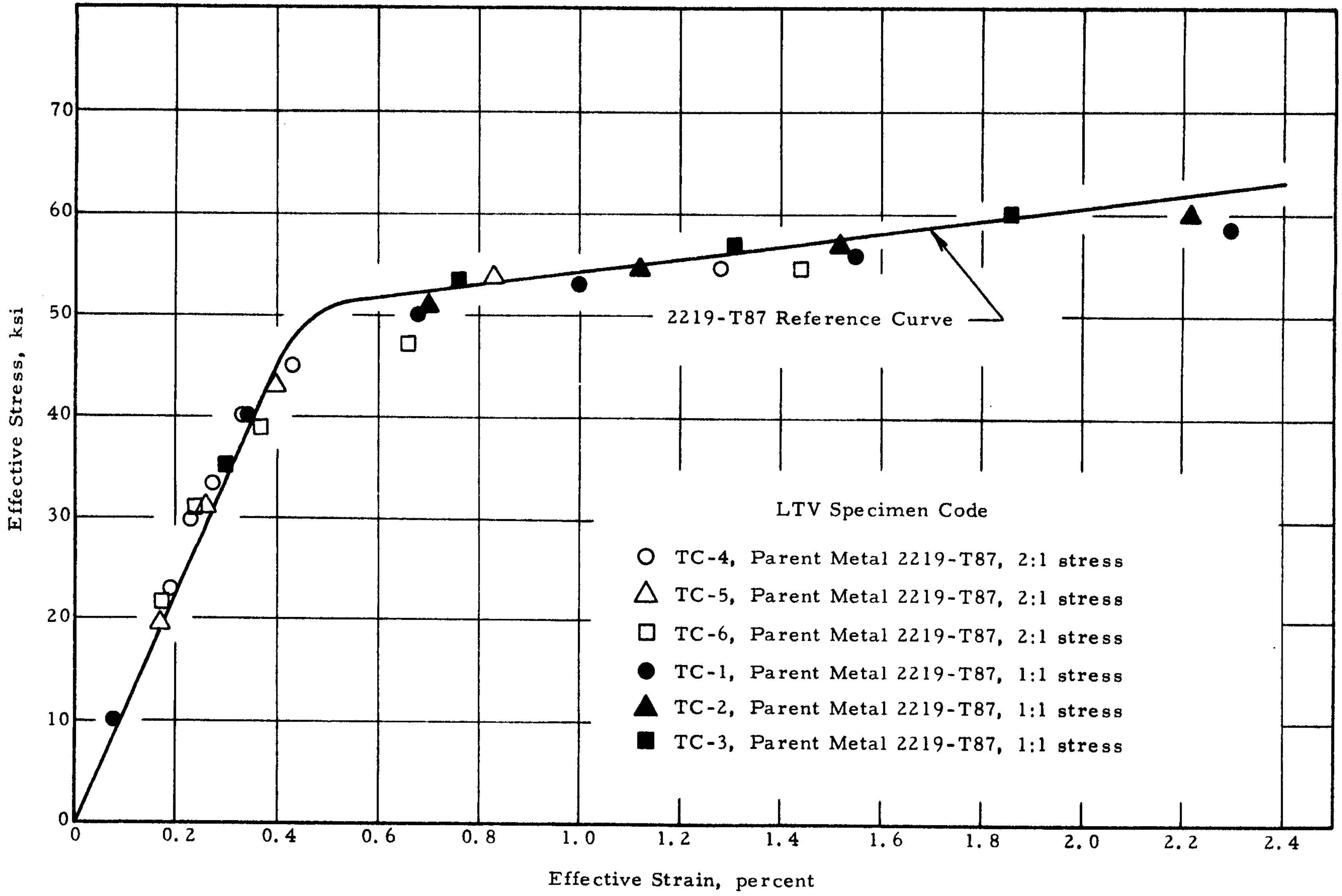


FIGURE A-15. LING-TEMCO-VOUGHT BIAXIAL DATA CONVERTED TO EFFECTIVE STRESS AND STRAIN

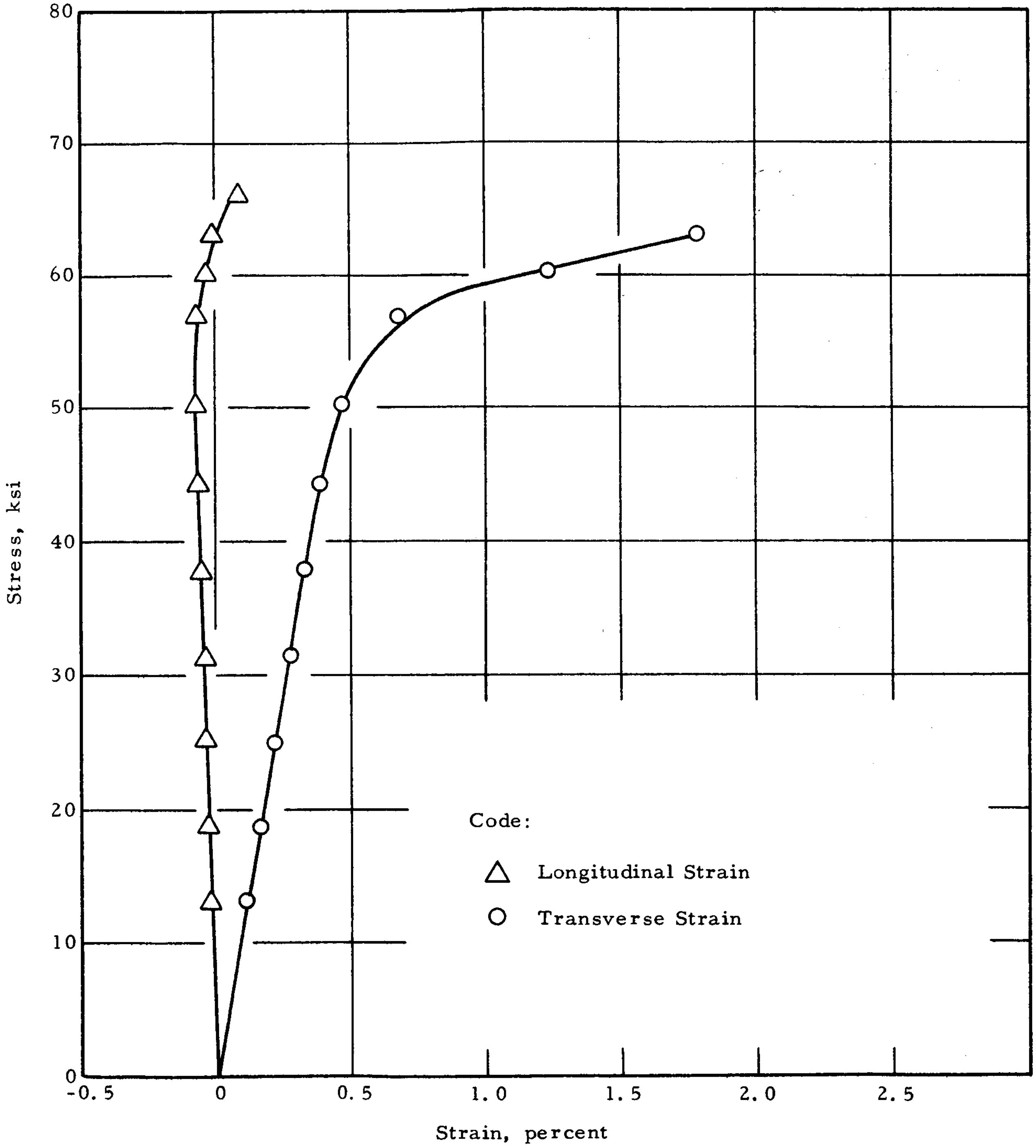


FIGURE A-16. STRESS-STRAIN DATA OBTAINED ON MIT SPECIMEN

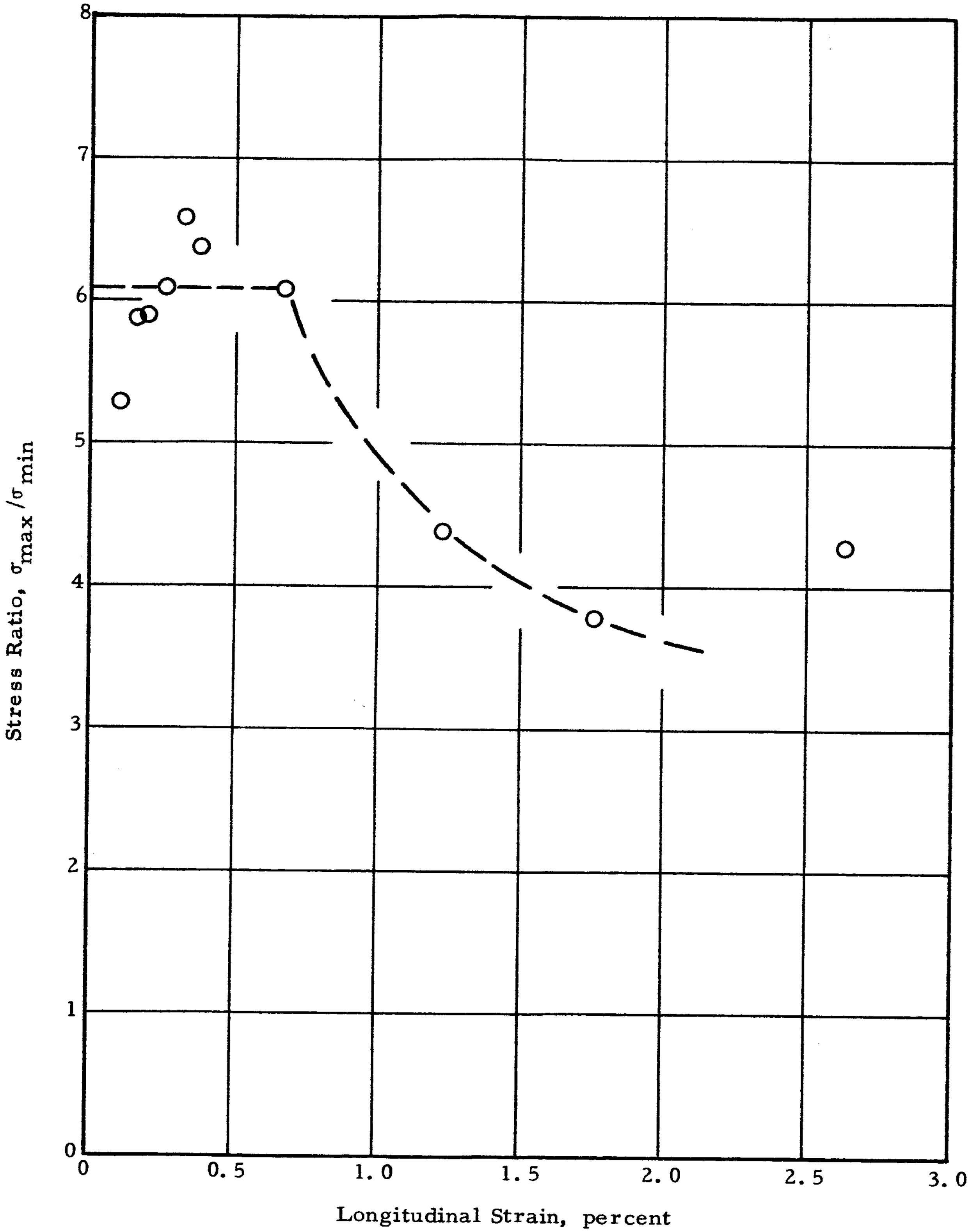


FIGURE A-17. STRESS RATIO IN MIT SPECIMEN AS A FUNCTION OF LONGITUDINAL STRAIN

G. Summary of Biaxial Strength Results

The biaxial strength of 2219-T87 parent metal was determined by four test methods. The average results, along with the average uniaxial tensile strength and the biaxial-to-uniaxial strength ratios, are presented in Table A-4. As illustrated in Figure A-18, the biaxial-to-uniaxial strengths agree well with the maximum conserved distortion energy theory, which is a modification of the distortion energy theory to take into account the strain hardening properties of the material.

The mean biaxial strengths of the TIG weldments were determined by three methods, and the results are summarized in Table A-5. These results appear to agree better with the maximum stress theory than with the maximum conserved distortion energy theory that the parent metal specimens followed, as shown in Figure A-19.

It appears that no one test method stands out as being universally applicable for the measurement of biaxial properties. Each test has its advantages and disadvantages.

The circular hydraulic bulge test was found to be suitable for determining the 1:1 biaxial strength of both parent metal and weldments. The welds can be tested in full cross section or with the crowns and dropthroughs removed. A 2:1 stress state was not achieved with the elliptical die design investigated.

The cylinder test was successfully employed to study welds subjected to three stress ratios (1:1, 2:1, 1:0). Other stress ratios can be obtained. However, the aluminum alloys investigated typically produced undermatched welds, which made it difficult to get a parent metal failure.

The LTV test worked well at both 1:1 and 2:1 stress ratios on parent metal. The specimen design presently used has a machined test section and does not permit the testing of welds in full cross section.

The MIT test is limited to 2:1 stress ratio, and that can be achieved only if a large amount of plastic deformation occurs in the test section prior to failure. The machined test section used in this specimen results in the same limitations in testing welds that was encountered in the LTV specimen.

TABLE A-4. BIAXIAL AND UNIAXIAL ULTIMATE STRENGTH OF 2219-T87 ALUMINUM ALLOY

Test Method	Stress Ratio	No. of Biaxial Tests	Average Biaxial Strength	Biaxial/Uniaxial Ratios[(a)]
△ SwRI Bulge	1:1	3	66.4 ksi	1.01
○ LTV Biaxial	1:1	3	62.2 ksi	0.95
■ SwRI Cylinder	2:1	1	70.7 ksi	1.08
● LTV Biaxial	2:1	3	71.1 ksi	1.08
▲ MIT Biaxial	>2:1	5	71.5 ksi	1.09

(a) Uniaxial Tensile Strength of 2219-T87 = 65.8

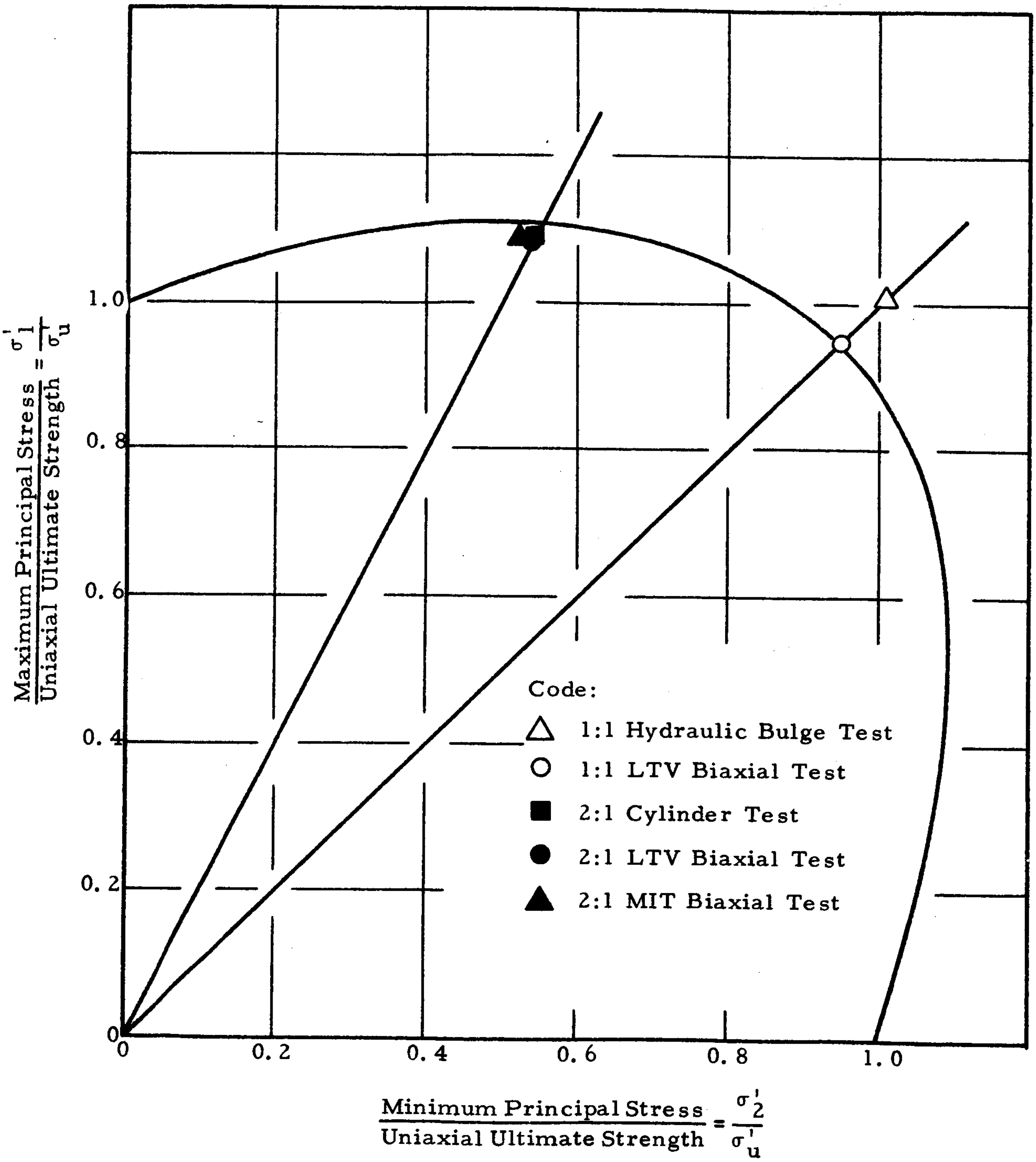


FIGURE A-18. COMPARISON OF MEAN BIAXIAL STRENGTH OF 2219-T87 PARENT METAL WITH MAXIMUM CONSERVED ENERGY THEORY. (Work Hardening Coefficient - 0.10)

TABLE A-5. BIAXIAL AND UNIAXIAL STRENGTH OF 2219-T87 ALUMINUM ALLOY TIG WELDED WITH 2319 FILLER

Test Method	Stress Ratio	No. of Biaxial Tests	Average Strength		Biaxial/Uniaxial Ratio
			Biaxial	Uniaxial	
△ SwRI Bulge (Single Weld)	1:1	3	44.6	41.3	1.08
▲ SwRI Bulge (Cross Weld)	1:1	3	42.1	41.8	1.01
□ SwRI Cylinder (Single Weld)	1:1	3	38.7	40.1	0.96
○ LTV Biaxial (Cross Weld)	1:1	3	41.4	37.2	1.11
■ SwRI Cylinder (Single Weld)	2:1	3	40.7	40.1	1.02
● LTV Biaxial (Cross Weld)	2:1	3	37.4	37.2	1.01

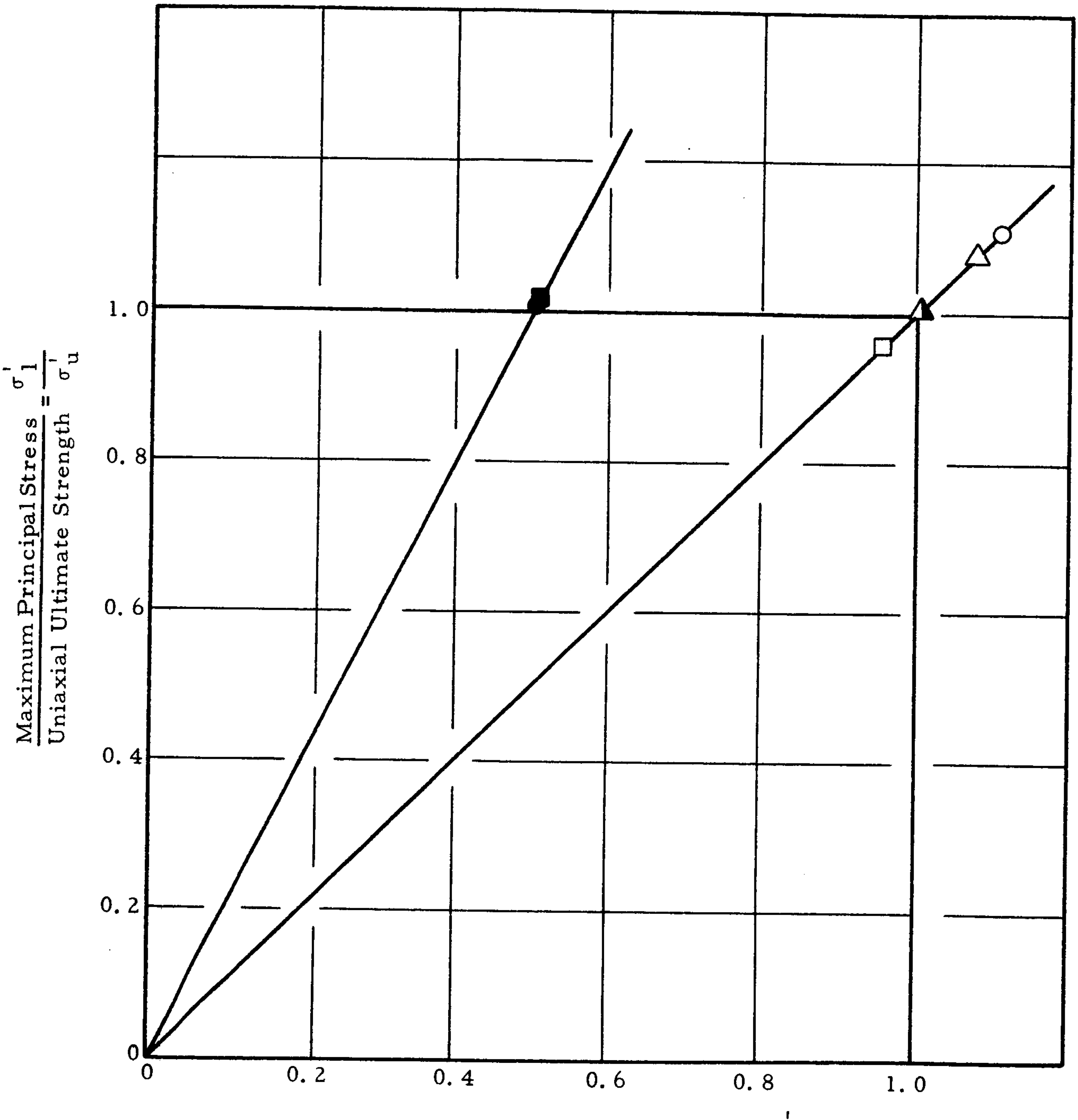


FIGURE A-19. COMPARISON OF BIAXIAL STRENGTH OF TIG 2219-T87 WELDMENTS WITH THE MAXIMUM STRESS THEORY

APPENDIX B

EVALUATION OF THE MECHANICAL PROPERTIES OF ALUMINUM ALLOY SHEET AND WELDMENTS SUBJECTED TO UNIAXIAL AND BIAXIAL STRESS FIELDS (NAS8-20160, PHASE II)

EVALUATION OF THE MECHANICAL PROPERTIES OF ALUMINUM ALLOY SHEET AND WELDMENTS SUBJECTED TO UNIAXIAL AND BIAXIAL STRESS FIELDS (NAS8-20160, PHASE II)

A. Introduction

This program consisted of a series of uniaxial tensile and circular hydraulic bulge tests on 1/8-inch 2219-T87, 2014-T6, and X7106-T63 parent metal and weldments. The hydraulic bulge test was chosen for biaxial load testing over the other test methods for the following reasons:

(1) The welds were expected to have joint efficiencies low enough to make it difficult if not impossible to determine parent metal properties with the cylinder test.

(2) It was desired to test the weld with bead and dropthrough intact. Both the LTV and MIT biaxial test specimens require a reduced test section which would necessitate machining a portion of the weld away.

(3) Use could be made of data generated in NAS8-1529 to permit the application of statistics in the analysis of the results.

The primary emphasis was placed on fully heat treated parent metal and on welded panels in the naturally aged condition. A limited investigation into the properties of annealed panels and stress relieved panels of parent metal and weldments was also conducted. A summary of the complete test program is given in Table B-1.

All specimens were prepared and tested as described in Appendix E. Details of welding procedures and heat treatments for the three aluminum alloys are given in Appendix F.

B. Properties of Fully Heat Treated Parent Metal and Naturally Aged Weldments

Three hydraulic bulge tests were conducted on each of three aluminum alloys - 2219-T87, 2014-T6, and X7106-T63. The membrane stress (PR/2t) was calculated as a function of the applied pressure. The maximum value of this stress, which usually occurred prior to specimen fracture, was taken as the ultimate biaxial strength. The results are listed in Table B-2. Also

TABLE B-1. PHASE II TEST PROGRAM (NAS8-20160)

Alloy	Welding Process	Filler Metal	Weld Configurations	Quantity per Condition As Welded	Annealed[a]	Relieved[b]
2014-T6	None	-	-	3	1	1
2219-T87	None	-	-	3	1	1
X7106-T63	None	-	-	3	1	1
2014-T6	TIG	2319	Single	3	1	1
2014-T6	TIG	4043	Single	3	1	1
2014-T6	MIG	4043	Single	3	1	1
2219-T87	TIG	2319	Single	3	1	1
2219-T87	TIG	2319	Cross	3	-	-
2219-T87	MIG	2319	Single	3	1	1
X7106-T63	TIG	X5180	Single	3	1	1

(a) Annealing Heat Treatment: 775°F/2 hours/furnace cool to 300°F, air cool to RT.

(b) Stress Relief Treatment: 525°F/5 hours/air cool.

TABLE B-2. SUMMARY OF BIAXIAL AND UNIAXIAL STRENGTHS OF 2219-T87, 2014-T6, AND X7106-T63 PARENT METAL

Alloy	Biaxial			Uniaxial			
	No. of Tests	Avg Ult Str, ksi	Min/Max ksi	No. of Tests	Avg Ult Str, ksi	Std Dev, ksi	99% LTL, ksi
2219-T87	3	66.4	64.5/67.4	15	65.8	0.71	63.3
2014-T6	3	74.2	72.9/76.0	15	70.4	1.26	66.0
X7106-T63	3	70.0	67.8/71.1	15	64.9	0.52	63.1

included in Table B-2 are the uniaxial strengths of each alloy. The average uniaxial and biaxial strengths are presented graphically in Figure B-1. Examination of this figure shows that 2014-T6 is somewhat stronger than either of the other two alloys. Also, the 2219-T87 material had a slightly higher uniaxial strength but a slightly lower biaxial strength than the X7106-T63 alloy.

The average value of the membrane stress as a function of $(P)^{2/3}$ is presented in Figures B-2, B-3, and B-4 for 2219-T87, 2014-T6, and X7106-T63, respectively. As discussed in Appendix A, the linear dependence of the bulge panel stress on $(P)^{2/3}$ in the elastic region was confirmed by stress analysis. This linear dependence does not hold in the plastic region; however, the relationship between stress and $(P)^{2/3}$ may be established experimentally, thus providing a convenient method for evaluating weldments in which the ultimate strength of the weld exceeds the yield strength of the parent metal.

Three bulge tests and five uniaxial tensile tests were performed on each welding process/parent metal/filler metal combination in the as-welded (naturally aged) condition. The 2219-T87 and 2014-T6 weldments were tested approximately two weeks after welding. The X7106-T63 welded panels were naturally aged for six weeks before testing.

The biaxial strength of each welded panel was determined from the curves of Figures B-2, B-3, and B-4. The two-thirds power of the pressure at failure was calculated for each panel, and the stress was read from the appropriate curve. If the $(P)^{2/3}$ value corresponded to a stress past the peak of the curve, the biaxial ultimate strength was taken as the maximum value of the curve.

The biaxial and uniaxial ultimate strengths obtained on welded panels are summarized in Table B-3. The average strength values of the naturally aged test panels, along with the range of individual results, are given in Figure B-5.

The TIG X7106-T63/X5180 weldments exhibited the highest uniaxial tensile strength (51.3 ksi) of all specimens tested. The TIG 2014-T6/2319, TIG 2014-T6/4043, and MIG 2014-T6/4043 welds had intermediate strengths, while the TIG 2219-T87/2319 specimens had the lowest (41.6 ksi).

On the basis of biaxial strength, the TIG X7106-T63/X5180 welds were again the strongest (48.4 ksi), followed in order by TIG 2014-T6/2319, TIG 2014-T6/4043, MIG 2319-T87/2319, TIG 2219-T87/2319, and MIG 2014-T6/4043 (40.5 ksi).

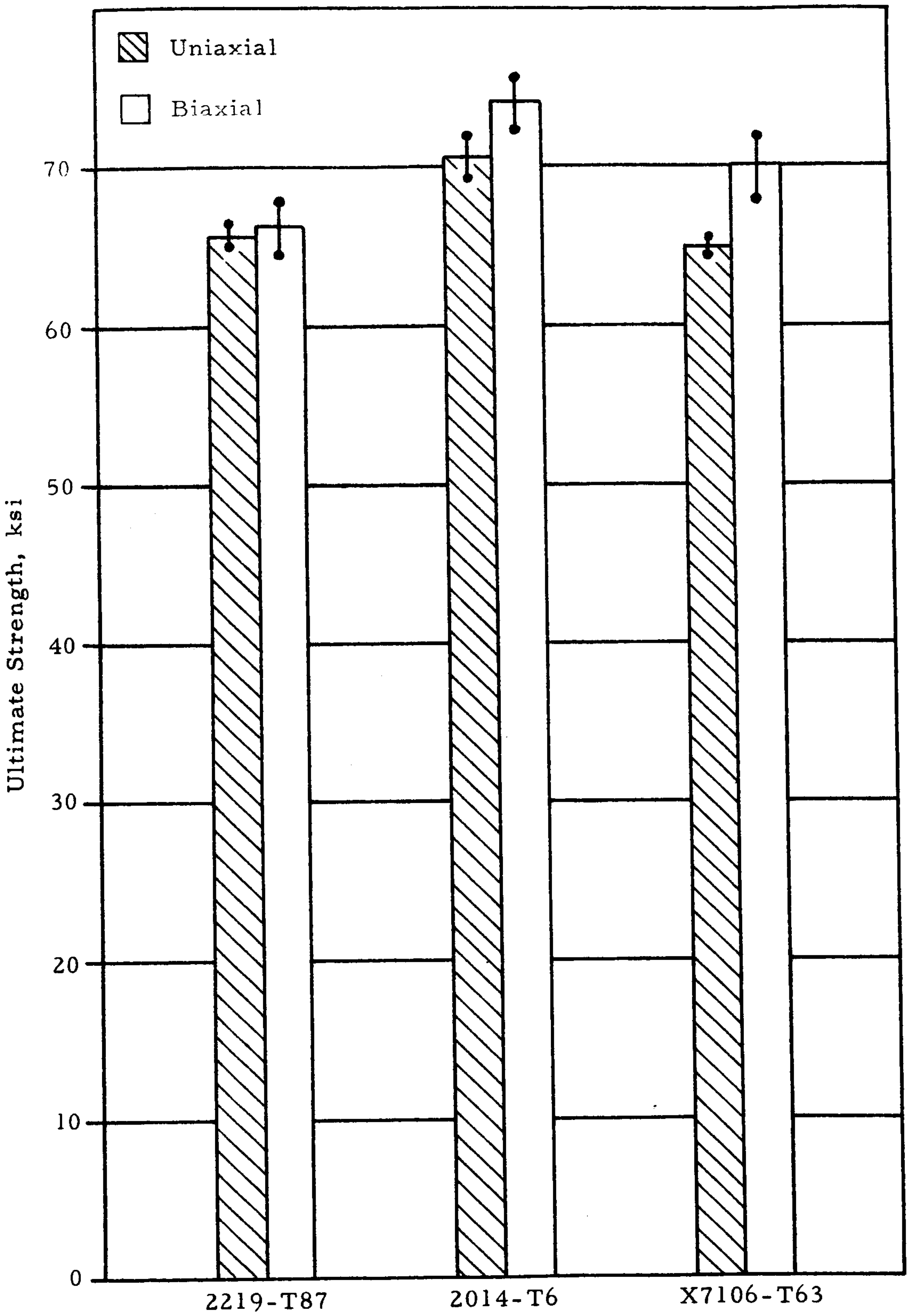


FIGURE B-1. THE BIAXIAL AND UNIAXIAL STRENGTHS OF 2219-T87, 2014-T6, AND X7106-T63 HIGH STRENGTH ALUMINUM ALLOYS

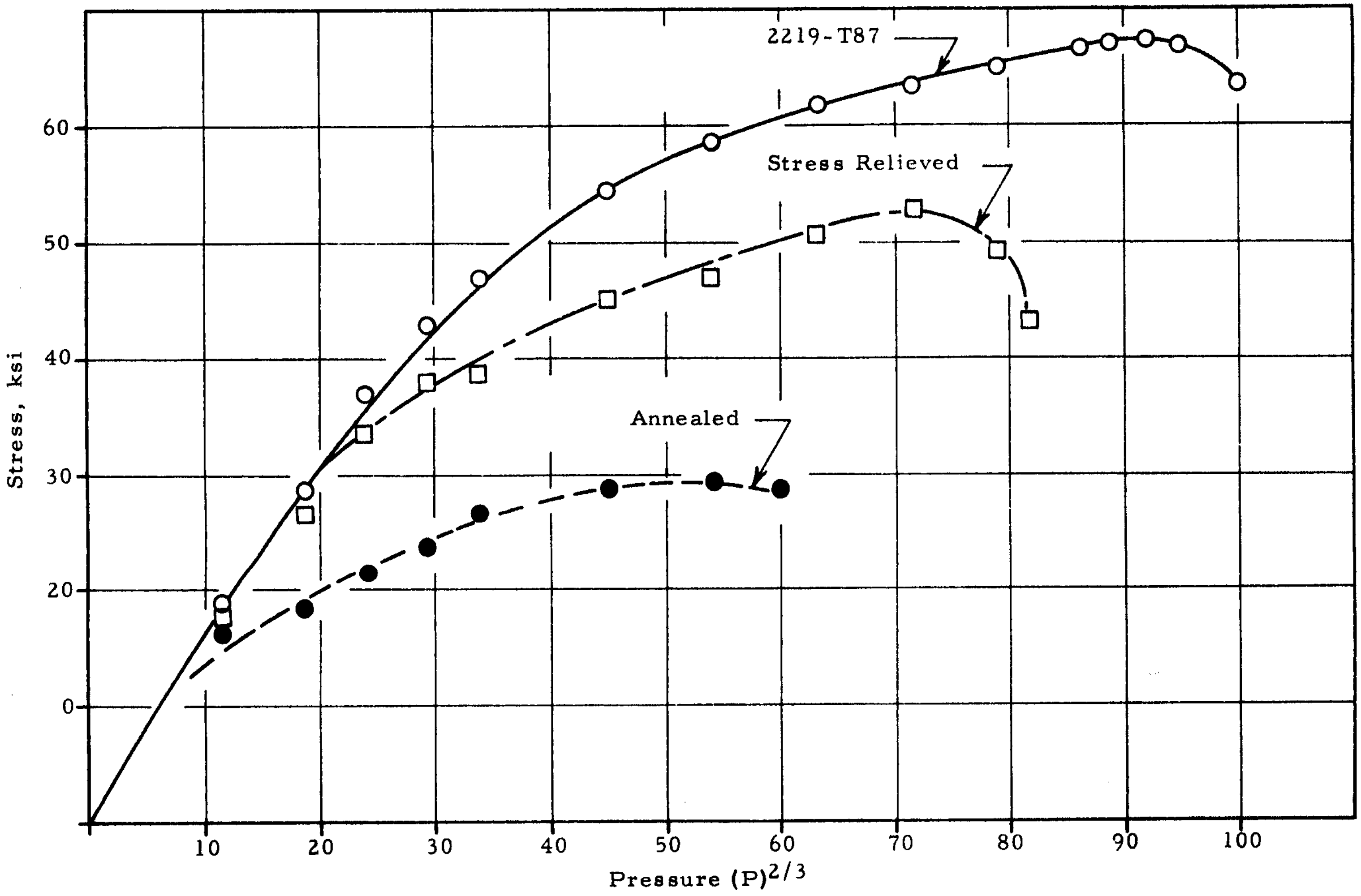


FIGURE B-2. BULGE PANEL STRESS AS A FUNCTION OF THE TWO-THIRDS POWER OF THE APPLIED PRESSURE FOR 2219 ALUMINUM ALLOY

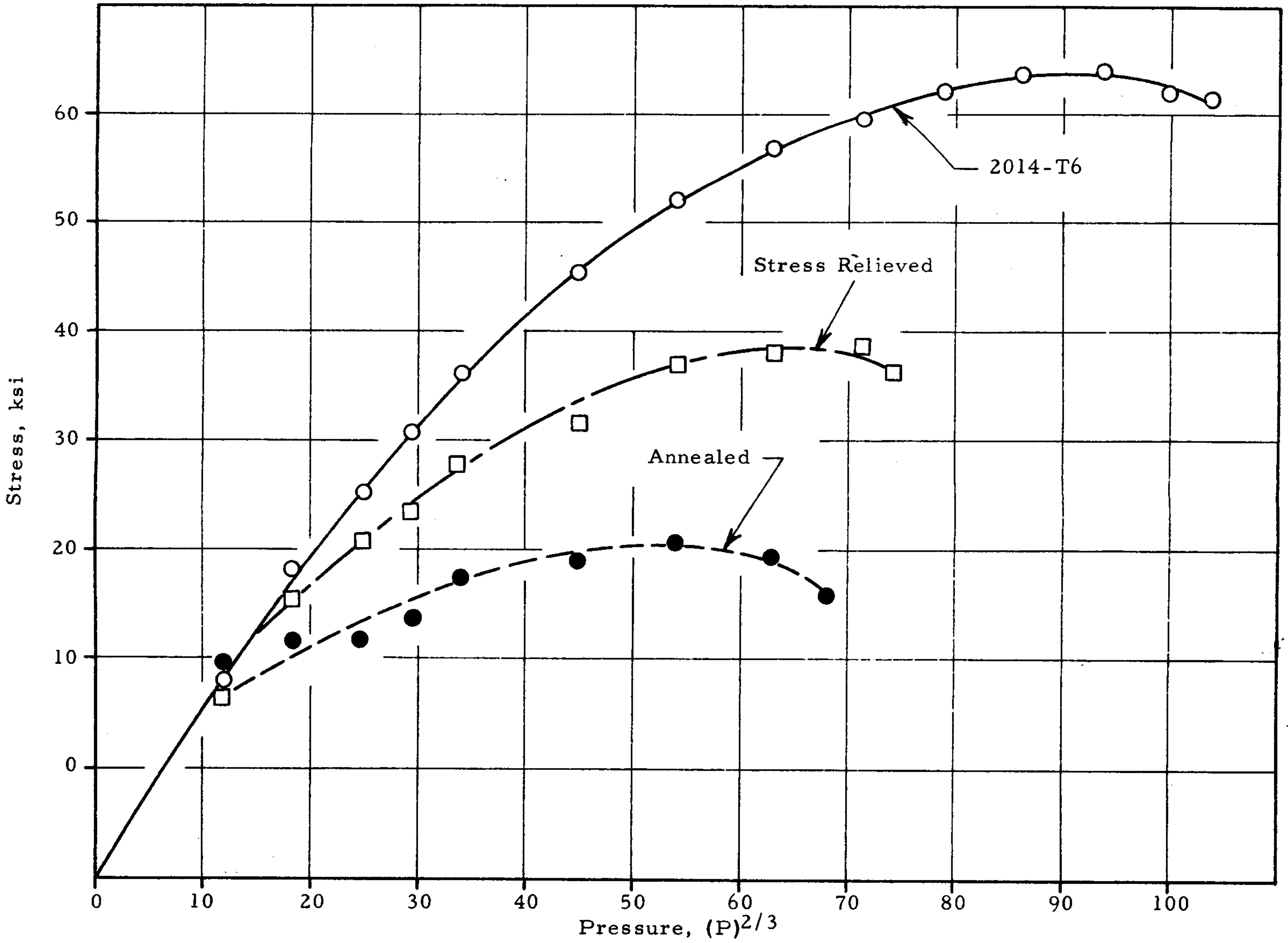


FIGURE B-3. BULGE PANEL STRESS AS A FUNCTION OF THE TWO-THIRDS POWER OF THE APPLIED PRESSURE FOR 2014 ALUMINUM ALLOY

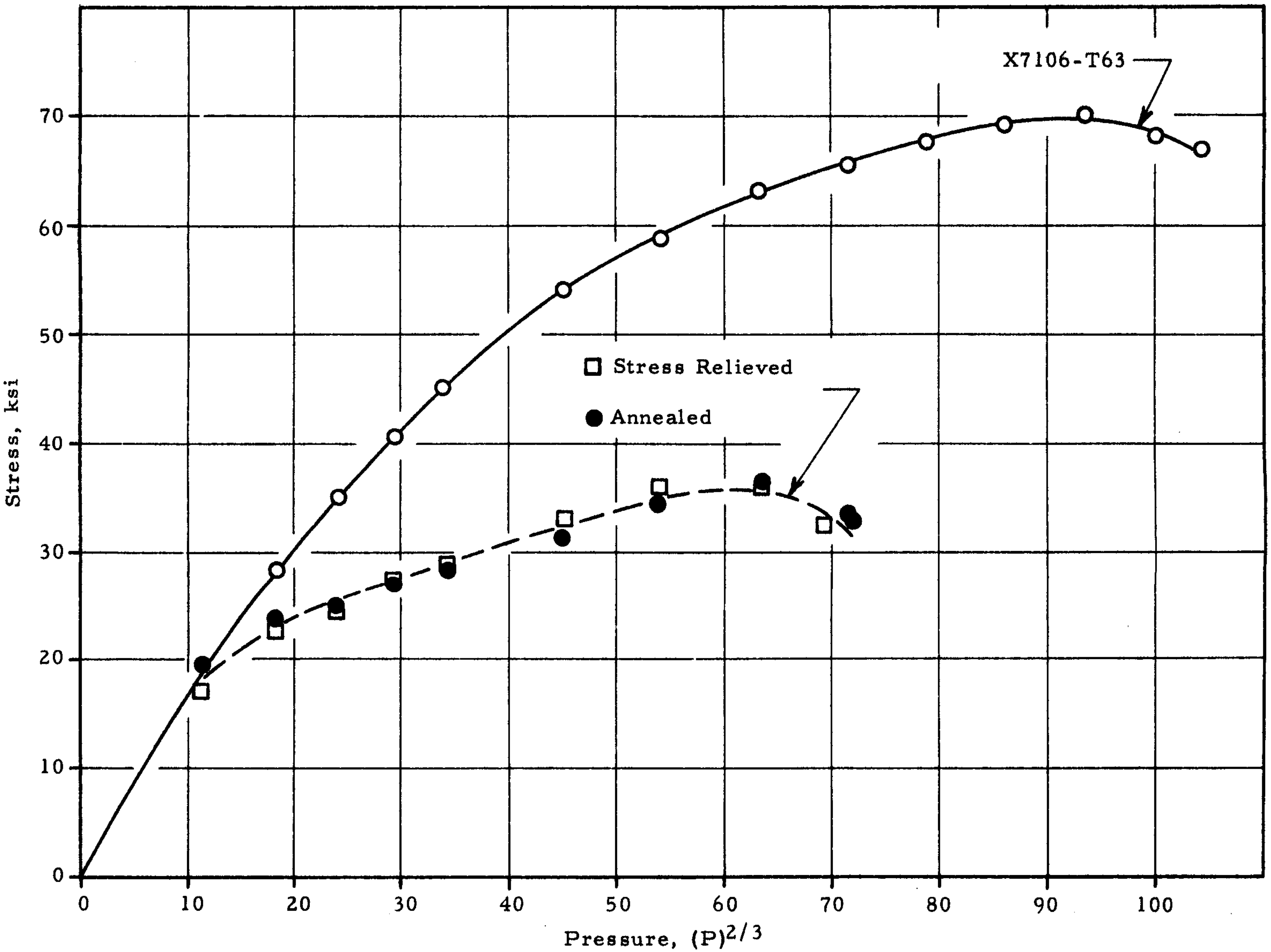


FIGURE B-4. BULGE PANEL STRESS AS A FUNCTION OF THE TWO-THIRDS POWER OF THE APPLIED PRESSURE FOR X-7106 ALUMINUM ALLOY

TABLE B-3. SUMMARY OF BIAXIAL AND UNIAXIAL STRENGTHS OF NATURALLY AGED 2219-T87, 2014-T6, AND X7106-T63 WELDMENTS

	Biaxial			Uniaxial			
Weldment Type	No. of Tests	Avg Ult Str, ksi	Min/Max, ksi	No. of Tests	Avg Ult Str, ksi	Std Dev, ksi	99% LTL, ksi
TIG 2219-T87/2319 Single	3	44.6	43.8/46.0	30	41.3	1.97	35.2
TIG 2219-T87/2319 Cross	3	42.1	41.8/42.5	29	41.8	1.87	36.1
MIG 2219-T87/2319 Single	3	43.7	40.6/46.6	15	43.0	1.35	38.3
TIG 2014-T6/2319 Single	3	45.4	43.1/47.6	15	49.8	2.90	39.5
TIG 2014-T6/4043 Single	3	44.2	42.0/48.5	15	47.7	1.67	41.8
MIG 2014-T6/4043 Single	3	40.5	39.7/41.2	15	44.7	1.06	40.9
TIG X7106-T63/X5180 Single	3	48.4	47.3/49.2	15	51.3	2.45	42.7

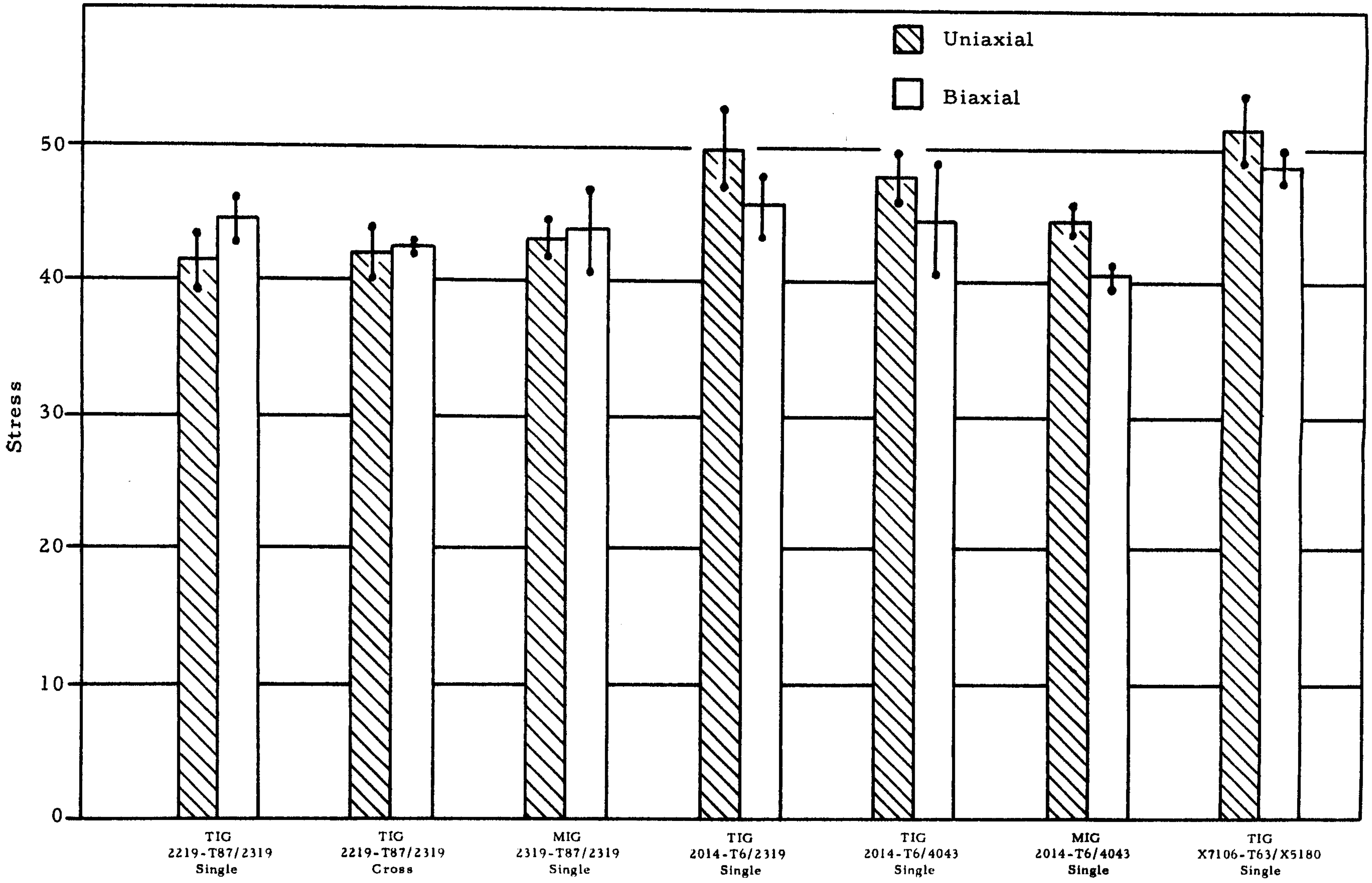


FIGURE B-5. THE BIAXIAL AND UNIAXIAL STRENGTHS OF NATURALLY AGED 2219-T87, 2014-T6, AND X7106-T63 WELDMENTS

In Mod 6 of NAS8-1529, a large number of circular hydraulic bulge tests had been performed on 2219-T87 and 2014-T6 parent metal and weldments. In this program, the biaxial strengths had been calculated with the membrane stress formula (PR/2t)(4). The biaxial strengths of the weldments were recalculated, using Figures B-2 and B-3, and the new results are given in Table B-4. The differences in the biaxial strengths of the single, tee and cross welds in each alloy system are of the same order of magnitude as the range of results. Therefore, the three types of configurations may be treated as a single group.

The data in Tables B-3 and B-4 were combined to calculate the mean, the standard deviation, and the lower tolerance limit of the biaxial ultimate strength of five parent metal/welding process/filler metal combinations. The results are given in Table B-5 and Figure B-6. Also included is the analysis of the uniaxial tensile data from both programs.

The combined uniaxial tensile test results essentially confirm the conclusions reached in the Fourth Annual Summary Report. Using the newly developed biaxial stress calculation procedure, the conclusions based on biaxial strength are somewhat different, however.

Agreeing with last year's conclusions, the TIG/2014-T6/4043 weldments were superior to the corresponding MIG weldments based on either the mean values or the lower tolerance limits of the uniaxial and biaxial ultimate strengths.

Also supporting the previous conclusions, the TIG/2014-T6/2319 weldments exhibited a uniaxial strength comparable to that of the TIG/2014-T6/4043 group. Contrary to last year's analysis, the biaxial strengths now confirm the similarity of the strengths of the TIG/2014-T6 welds using either filler metal.

Again agreeing with last year's conclusions, no significant differences were observed in the mean values of biaxial and uniaxial ultimate strengths of TIG and MIG 2219-T87/2319 weldments. The new results indicate that the lower tolerance limit of the biaxial strength of the TIG/2219-T87/2319 weldment is higher than the corresponding MIG weld rather than lower as previously reported.

Based on the mean values, the biaxial-uniaxial strength ratio of the welds are as follows:

TABLE B.4. SUMMARY OF BIAXIAL AND UNIAXIAL STRENGTHS OF 2219-T87 AND 2014-T6 WELDMENTS TESTED IN NAS8-1529, MOD 6

Weldment		Biaxial			Uniaxial			
Type	Configuration	No. of Tests	Avg Ult Str, ksi	Min/Max, ksi	No. of Tests	Avg Ult Str, ksi	Std Dev, ksi	99% LTL, ksi
TIG	Single	3	43.3	42.1/44.2	48	43.5	2.20	37.2
2219-T87	Tee	3	44.3	43.3/46.2				
2319	Cross	3	43.7	43.3/44.2				
MIG	Single	3	43.2	41.4/46.5	46	42.7	1.91	37.2
2219-T87	Tee	3	45.8	44.5/47.5				
2319	Cross	4	46.2	43.5/48.1				
TIG	Single	3	51.7	51.3/52.3	32	50.0	2.84	41.4
2014-T6	Tee	3	46.2	44.2/47.8				
2319	Cross	2	48.8	47.8/49.8				
TIG	Single	2	44.8	44.2/45.5	39	47.9	4.74	33.9
2014-T6	Tee	3	44.0	43.4/44.5				
4043	Cross	3	43.6	43.2/44.2				
MIG	Single	3	38.2	37.0/40.5	37	42.1	4.14	29.9
2014-T6	Tee	3	41.8	37.8/44.5				
4043	Cross	3	36.1	35.3/36.8				

TABLE B-5. COMBINED RESULTS OF FOURTH YEAR AND FIFTH YEAR UNIAXIAL AND BIAXIAL TESTS ON 2219-T87 AND 2014-T6 WELDMENTS

	Biaxial				Uniaxial			
Weldment Type	No. of Tests	Ult Str, ksi	Std Dev, ksi	99% LTL, ksi	No. of Tests	Ult Str, ksi	Std Dev, ksi	99% LTL, ksi
TIG 2219-T87 2319	15	43.6	1.27	39.1	78	42.7	2.38	36.1
MIG 2219-T87 2319	13	44.8	2.44	35.9	61	42.8	1.78	37.8
TIG 2014-T6 2319	11	48.0	3.05	36.2	47	49.9	2.84	41.8
TIG 2014-T6 4043	11	44.1	1.77	37.3	54	47.9	4.11	36.2
MIG 2014-T6 4043	12	39.1	2.92	28.2	52	42.9	3.71	32.3

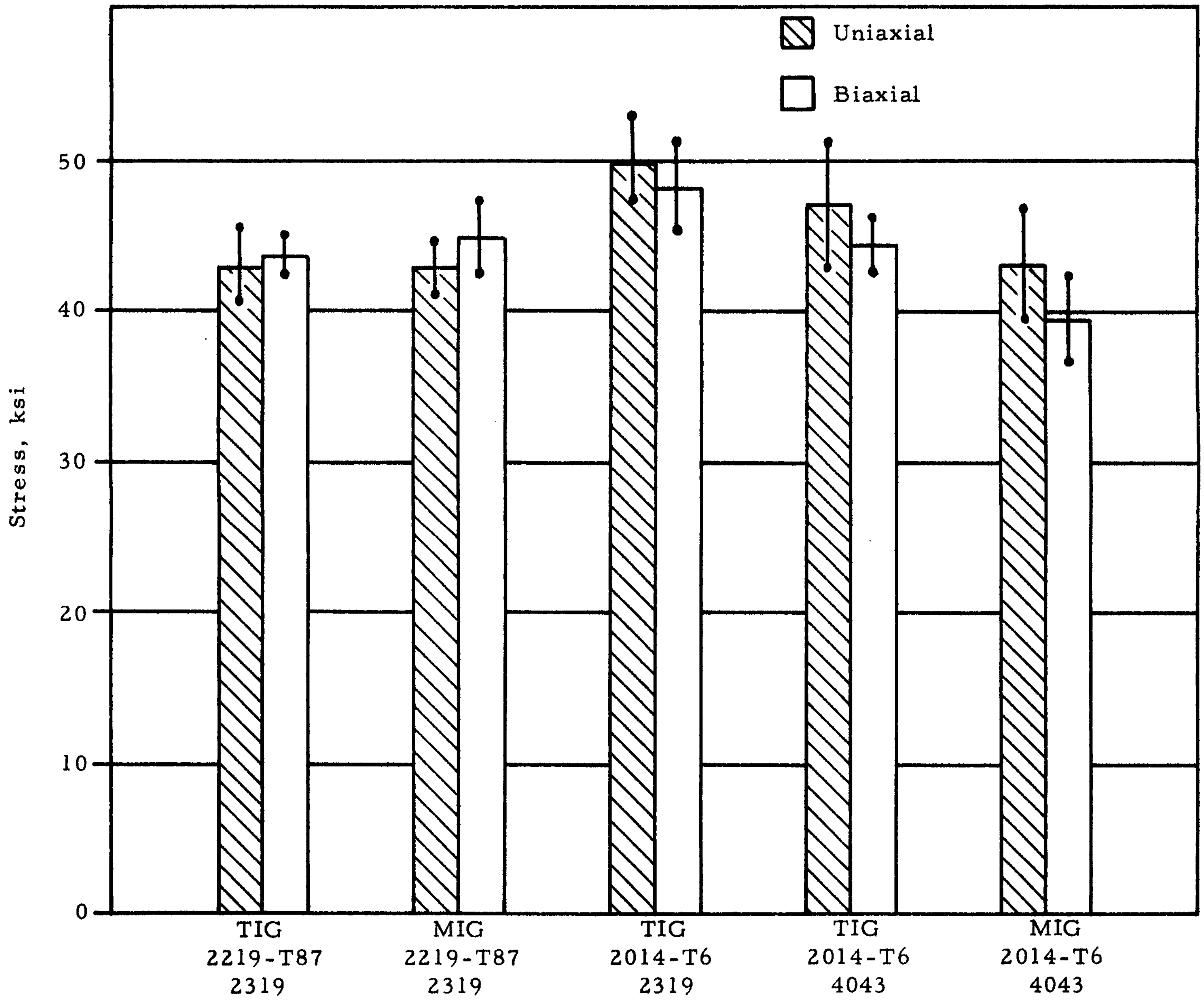


FIGURE B-6. THE BIAXIAL AND UNIAXIAL STRENGTHS OF 2219-T87 AND 2014-T6 WELDMENTS PRODUCED DURING THE FOURTH AND FIFTH YEARS OF THE PROGRAM

Combination	Biaxial/Uniaxial Strength Ratio
TIG/2219-T87/2319	1.02
MIG/2219-T87/2319	1.05
TIG/2014-T6/2319	0.96
TIG/2014-T6/4043	0.92
MIG/2014-T6/4043	0.91

This indicates that for 2014-T6/4043 and 2219-T87/2319 welds, the welding process had no significant effect on the biaxial/uniaxial strength ratio.

C. Effect of Annealing and Stress Relief Heat Treatments

One circular bulge test and five uniaxial tensile tests were performed on each weldment in each heat-treated condition. This sample size was selected to provide preliminary trend information only.

The properties of the annealed and stress relieved panels are given in Table B-6. It can be seen that, with one exception, the annealed weldments had essentially the same uniaxial and biaxial properties as the annealed parent materials. The exception was the MIG 2014-T6/4043 weld. Although its uniaxial strength was comparable, the biaxial strength of this panel was approximately 80 percent of all other annealed 2014 specimens.

Although the stress relieving treatment overaged all three parent metals, thus reducing their strength, the effect of this treatment on the strength of the welds was quite varied. The uniaxial strengths of the TIG and MIG 2219-T87/2319 welds were slightly increased although the biaxial strengths were not affected. The biaxial and uniaxial strengths of the TIG 2014-T6/2319 and the TIG 2014-T6/4043 specimens were essentially unaffected. The biaxial strength of the MIG 2014-T6/4043 weldment was reduced even though the uniaxial strength was not changed The properties of the TIG X7106-T63/X5180 welds were reduced to the same level as those which were annealed.

TABLE B-6. BIAXIAL AND UNIAXIAL PROPERTIES OF ANNEALED AND STRESS RELIEVED 2219-T87, 2014-T6, AND X7106-T63 PARENT METAL AND WELDMENTS

		Biaxial		Uniaxial			
Panel Type	Heat Treatment[(a)]	No. of Tests	Ult Str, ksi	No. of Tests	Ult Str, ksi	Std Dev, ksi	99% LTL, ksi
2219	Ann	1	29.5	5	30.8	0.46	28.2
2014	"	1	30.4	5	29.8	0.30	28.0
X7106	"	1	35.9	5	35.0	0.17	34.1
TIG/2219-T87/2319	"	1	29.3	5	30.7	0.13	30.0
MIG/2219-T87/2319	"	1	29.5	5	33.1	0.34	31.1
TIG/2014-T6/2319	"	1	30.4	5	29.6	0.19	28.4
TIG/2014-T6/4043	"	1	30.4	5	29.4	0.11	28.8
MIG/2014-T6/4043	"	1	24.7	5	29.6	0.21	28.4
TIG/X7106-T63/X5180	"	1	35.9	5	35.0	0.42	32.6
2219	SR	1	53.1	5	56.5	0.67	52.6
2014	"	1	48.5	5	51.6	0.68	47.7
X7106	"	1	35.7	5	39.4	0.37	37.3
TIG/2219-T87/2319	"	1	44.0	5	50.1	1.26	42.9
MIG/2219-T87/2319	"	1	44.0	5	48.3	0.42	45.8
TIG/2014-T6/2319	"	1	44.5	5	47.0	1.01	41.2
TIG/2014-T6/4043	"	1	41.7	5	47.4	0.51	44.5
MIG/2014-T6/4043	"	1	32.7	5	44.4	1.05	38.3
TIG/X7106-T63/X5180	"	1	35.7	5	39.5	0.15	38.7

(a) Ann: Heat to 775°F, hold 5 hours, furnace cool to 300°F, air cool to RT.
SR: Stress Relief Treatment; 525°F/5 hours/air cool.

APPENDIX C

INVESTIGATION OF THE WELDABILITY OF X7106-T63 ALUMINUM ALLOY

(NAS8-20160, Phase III)

INVESTIGATION OF THE WELDABILITY OF X7106-T63 ALUMINUM ALLOY

One phase of the program conducted under Contract NAS8-20160 was organized to evaluate the weldability of X7106-T63 aluminum alloy. This program included an investigation of the natural aging characteristics of weldments of this alloy and a study of the susceptibility of such weldments to hot cracking. The investigation of the natural aging characteristics was carried out on MIG and TIG weldments of X7106-T63 sheet and plate in 0.187 inch, 0.50 inch, and 1.00 inch thicknesses made with three potentially applicable filler metals. The crack susceptibility tests were performed on special specimens of 0.125-inch sheet designed to provide varying restraint along the length of the test weld. These tests also utilized three different filler metal alloys.

A. Natural Aging Characteristics of X7106-T63 Weldments

The program to establish the natural aging characteristics of X7106-T63 weldments consisted of a series of uniaxial tensile tests and hardness measurements on weldments of three thicknesses aged for periods of up to 12 weeks. The combinations of plate thickness, welding process, filler metal, and joint configuration included in this phase of the program are listed in Table C-1. For this portion of the program, welded panels were presented to provide the necessary tensile specimens and hardness test specimens (see Appendix E). Welding procedures were developed for each type of weldment by preparing various weldments with a range of welding parameters. In each case, selection of the final procedure was based on weld bead appearance and radiographic inspection. Details of the welding processes and inspection procedures employed in fabrication of the test panels are described in Appendix F. The final procedures adopted for each type of X7106-T63 weldment are listed as procedures 65A-2 through 65A-23 in Table F-1.

Results of the individual tests conducted in this portion of the program are listed in Appendix J. In summarizing these results, standard deviations and lower tolerance limits were computed by the procedures described in Appendix K.

1. 0.187-Inch X7106-T63 Weldments

The study of the aging characteristics of 0.187-inch X7106-T63 weldments included both MIG and TIG weldments made with X5180, 5356, and

TABLE C-1. PHASE III WELDMENTS

Plate Thickness	Welding Process	Joint Configuration	Filler Metal
0.187 Inch	TIG	Sq Butt	X5180 5356 5556
	MIG	Sq Butt	
0.50 Inch	TIG	Sq Butt	
		Double V*	
	MIG	Double V*	
1.00 Inch	TIG	Double V*	
	MIG	Double V*	

*Joint Configuration in Accordance with NASA SP-5009

5556 filler alloys. All welds in this portion of the investigation were made with square-butt joints.

In general, all types of 0.187-inch weldments exhibited similar aging behavior. Increases in ultimate strength and yield strength in the order of 20 percent of the as-welded values were observed for the 0.187-inch weldments after aging periods of 12 weeks. The typical aging characteristics of this group of weldments are illustrated in Figure C-1. The results of the tensile tests conducted on the 0.187-inch weldments are summarized in Tables C-2 and C-3. The average tensile properties of the weldments after an aging period of 12 weeks are presented in Figure C-2.

Among the six types in this group, the MIG/X5180 weldments exhibited the highest average ultimate strength (56.8 ksi). The average ultimate strengths of the TIG/X5180, MIG/5356, and MIG/5556 weldments were comparable (54.7 to 55.6 ksi) and slightly lower than that of the MIG/X5180 weldments. The TIG/5356 and TIG/5556 weldments exhibited the lowest ultimate strengths measured for this group (52.8 and 53.5 ksi, respectively). It should also be noted that the degree of scatter in the measured values of ultimate strength for the MIG/X5180 weldments was lower than that of any of the other weldments in this group. As a result, the MIG/X5180 weldments also exhibited the highest value of the computed lower tolerance limit of ultimate strength (see Table C-3). The TIG/X5180 weldments and all three types of MIG weldments had comparable yield strengths (39.9 to 40.3 ksi). The average yield strengths of the TIG/5356 and TIG/5556 weldments were somewhat lower than those of the others in this group (37.9 and 38.9, respectively).

In the fabrication of the test panels, more difficulties were encountered with the MIG process than with the TIG. In general, the MIG weldments were subject to more rejectable defects than were the TIG weldments. The bead configuration produced by the MIG process was less desirable and more difficult to control than that of the TIG weldments. In addition, the tensile test results indicate only small differences between the average ultimate strengths of the MIG/X5180 and TIG/X5180 weldments. Thus, taking the above factors into consideration, the TIG process, using X5180 filler wire, may be considered as the optimum process for welding the 0.187-inch sheet material.

2. 0.50-Inch X7106-T63 Weldments

The investigation of the tensile properties of 0.50-inch X7106-T63 weldments was conducted utilizing a double-V joint configuration for the MIG welds and both double-V and square-butt joints for the TIG welds. The two joint configurations were employed for the TIG weldments to establish

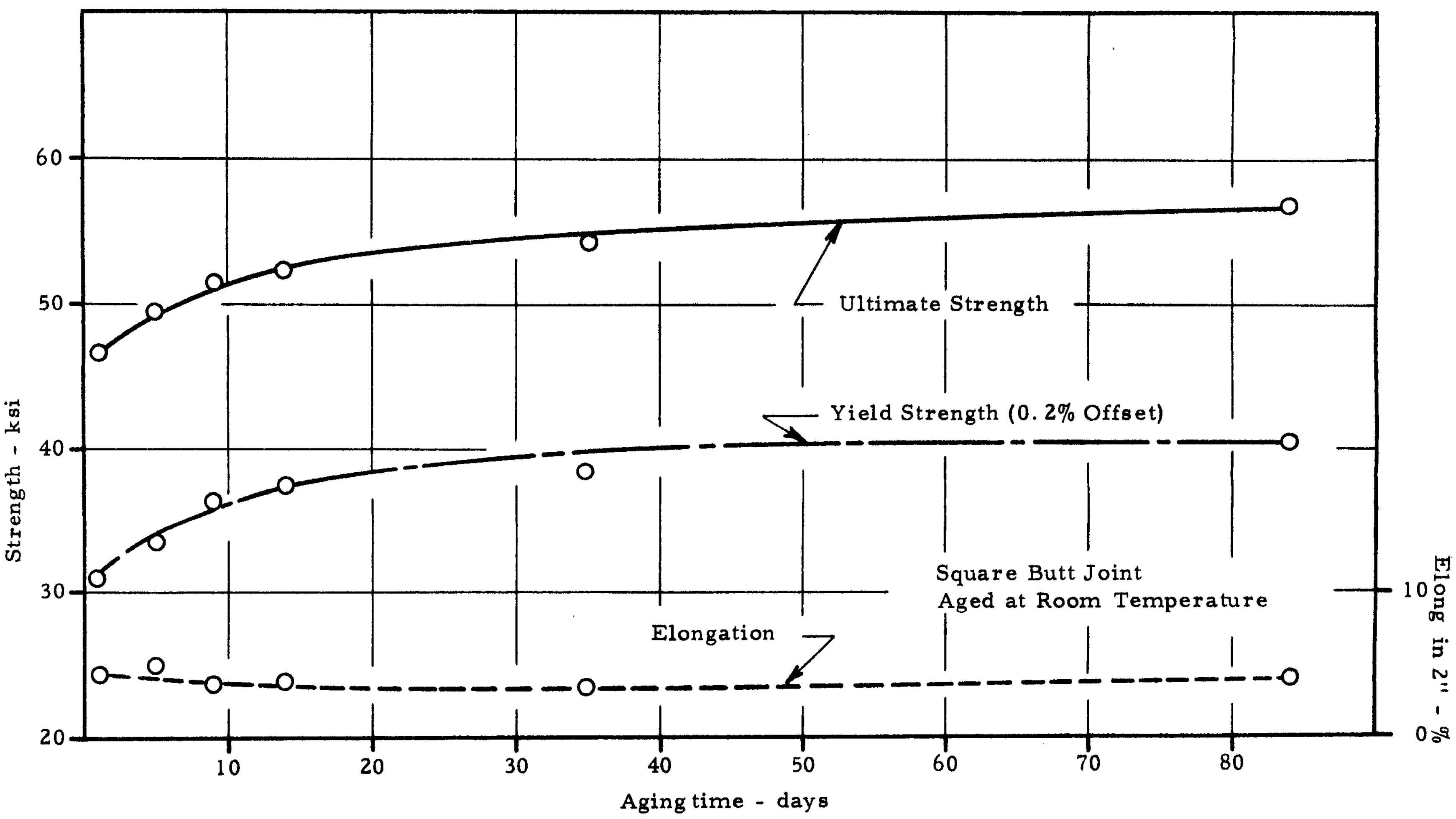


FIGURE C-1. TENSILE PROPERTIES OF 0.187-INCH MIG X7106-T63/X5180 WELDMENTS (Aging Characteristics Typical of 0.187-Inch Weldments Included in Study.)

TABLE C-2. SUMMARY OF TENSILE PROPERTIES OF 0.187-INCH TIG-X7106 WELDMENTS

Weldment Type	Panel No.	Aging Time	Yield Strength$^{(1)}$				Ultimate Strength				Elongation in 2 in.	
			No. of Tests	Avg. ksi	$S_y^{(2)}$ ksi	LTL$^{(3)}$ ksi	No. of Tests	Avg. ksi	$S_u^{(2)}$ ksi	LTL$^{(3)}$ ksi	Avg. %	$S_e^{(2)}$ %
TIG-X7106 X5180 Sq. Butt	CT3-1	1 day	6	29.3	1.39	22.2	6	43.2	1.52	35.5	3.8	0.47
		3 days	6	32.4	0.45	30.1	6	47.2	1.08	41.7	3.3	0.50
		1 week	6	33.1	0.08	27.6	6	48.3	1.12	42.7	3.3	0.57
		2 weeks	6	36.0	1.17	29.2	6	51.1	1.71	42.4	3.6	0.73
		5 weeks	6	38.4	0.88	34.0	6	54.0	1.51	46.4	3.2	0.39
		12 weeks	6	40.3	0.99	35.3	6	55.6	1.15	49.8	3.2	0.29
TIG-X7106 5356 Sq. Butt	CT4-1	1 day	6	29.1	0.71	25.5	6	43.2	0.80	39.1	3.8	0.72
		3 days	6	31.7	1.63	30.8	6	46.5	1.02	41.4	3.2	0.54
		1 week	6	32.8	1.00	27.7	6	47.2	1.13	41.5	3.4	0.24
		2 weeks	5	34.3	0.73	30.1	6	49.3	1.16	43.4	3.2	0.28
		5 weeks	6	36.6	0.43	34.4	6	51.4	1.11	45.7	3.4	0.35
		12 weeks	6	37.9	0.91	33.3	6	52.8	1.19	46.8	3.4	0.66
TIG-X7106 5556 Sq. Butt	CT5-5	1 day	6	29.7	0.94	24.9	6	43.4	1.54	35.5	3.6	0.66
		3 days	6	33.4	1.55	25.6	6	47.4	1.85	38.0	2.9	0.49
		1 week	6	33.3	1.08	27.1	6	47.4	1.65	39.0	2.9	0.83
		2 weeks	6	36.4	1.48	28.8	6	50.9	1.96	41.0	3.0	0.38
		5 weeks	5	37.4	0.53	34.8	6	51.8	1.23	46.1	3.3	0.28
		12 weeks	6	38.9	1.39	31.8	6	53.5	1.36	46.6	7.5	1.10

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)

TABLE C-3. SUMMARY OF TENSILE PROPERTIES OF 0.187-INCH MIG-X7106 WELDMENTS

Weldment Type	Panel No.	Aging Time	Yield Strength(1)				Ultimate Strength				Elongation in 2 in.	
			No. of Tests	Avg. ksi	S_y(2) ksi	LTL(3) ksi	No. of Tests	Avg. ksi	S_u(2) ksi	LTL(3) ksi	Avg. %	S_e(2) %
MIG-X7106 X5180 Sq. Butt	CM3-1	1 day	6	30.9	0.47	28.5	6	46.6	0.99	41.6	4.1	0.50
		5 days	6	33.6	0.14	32.9	6	49.3	1.28	42.8	4.7	2.02
		9 days	6	36.4	0.54	33.7	6	51.3	0.69	47.8	3.5	0.50
		2 weeks	6	37.1	0.49	34.6	6	52.2	1.40	45.1	3.7	0.40
		5 weeks	6	38.6	0.45	36.2	6	54.1	1.09	48.6	3.5	0.38
		12 weeks	6	40.4	0.59	37.3	6	56.8	0.84	52.5	4.0	0.35
MIG-X7106 5356 Sq. Butt	CM4-1	1 day	6	31.1	0.62	28.0	6	46.4	1.29	39.9	4.1	0.74
		5 days	6	33.1	0.20	32.1	6	47.9	1.27	41.5	4.2	0.90
		9 days	6	34.6	1.14	28.8	8	50.4	1.13	45.5	3.6	0.63
		2 weeks	6	35.7	0.60	32.6	6	51.7	1.37	44.8	3.9	0.60
		5 weeks	6	37.0	0.56	34.2	6	52.8	0.96	47.9	3.4	0.49
		12 weeks	6	39.3	0.66	36.0	6	54.8	1.71	46.1	3.7	0.77
MIG-X7106 5556 Sq. Butt	CM5-2	1 day	6	31.2	0.93	26.6	6	45.5	0.44	43.3	4.3	0.37
		5 days	6	33.5	0.47	31.1	6	48.5	1.47	41.0	4.1	0.71
		9 days	6	36.1	1.98	26.1	6	50.8	1.15	45.0	3.7	0.97
		2 weeks	6	36.3	0.20	35.3	6	51.4	0.70	47.8	3.9	0.26
		5 weeks	6	37.3	0.55	34.5	6	52.4	0.76	48.5	5.5	0.25
		12 weeks	6	39.9	0.52	37.2	6	54.7	1.06	49.4	3.7	0.51

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)

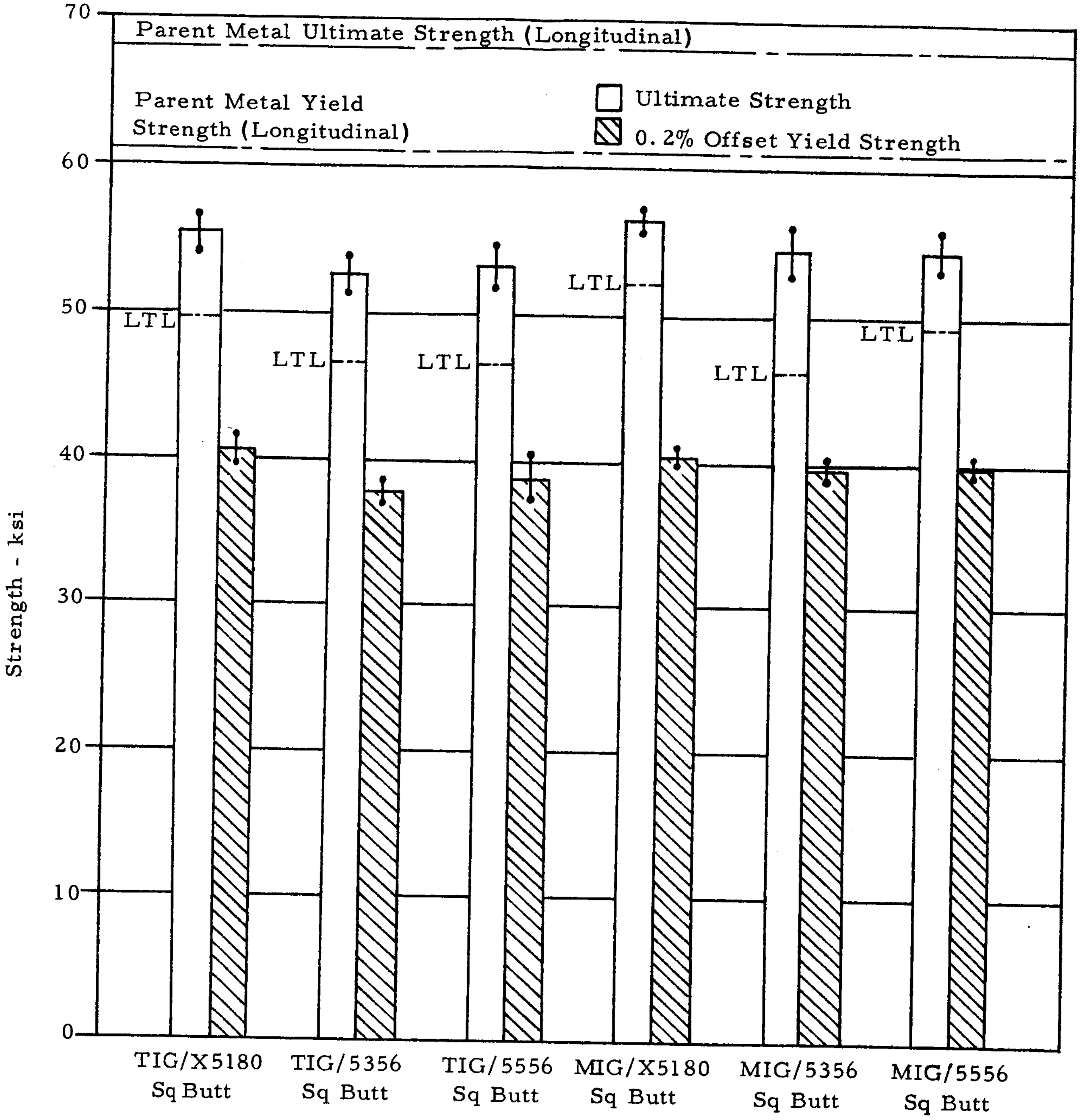


FIGURE C-2. TENSILE PROPERTIES OF 0.187-INCH TIG AND MIG X7106-T63 WELDMENTS AGED TWELVE WEEKS (Parent Metal Data from Ref. 4.)

any effect that dilution of the weld metal may have on the tensile properties of the weldments. Three filler wire alloys, X5180, 5356, and 5556, were used for the fabrication of the test panels.

The typical aging behavior of the 0.50-inch weldments is illustrated in Figure C-3. In this group of weldments, the maximum ultimate strength was attained after an aging period of approximately 30 days. Beyond this aging time, no significant increases in ultimate strength were noted. The tensile properties of each type of 0.50-inch weldment investigated in this portion of the program are summarized in Tables C-4 and C-5. The average ultimate strengths and yield strengths, measured after an aging period of 12 weeks, are plotted in Figure C-4.

Of all the 0.50-inch weldments tested, the TIG weldments exhibited average ultimate strengths slightly higher than or comparable to that recorded for the strongest MIG weldments (52.4 to 53.5 ksi). Within the group of TIG weldments, the ultimate strengths were comparable, regardless of joint design or filler wire alloy. The ultimate strengths of the MIG/X5180 and the MIG/5556 weldments were comparable (52.2 and 51.9 ksi) while the MIG/5356 weldments exhibited an average ultimate strength approximately 2.0 ksi lower than the other two 0.50-inch MIG weldments.

Comparison of the average tensile properties presented in Figure C-4 shows that the average yield strengths of all but three of the 0.50-inch weldments are comparable (34.8 to 36.7 ksi).

The two TIG double-V weldments made with 5356 and 5556 filler alloys exhibited average yield strengths somewhat lower than those of six types (34.2 and 33.5 ksi) while the average yield strength measured for the MIG/5356 weldments was significantly lower than all other types (29.7 ksi).

As was the case for the 0.187-inch X7106-T63 sheet, the TIG process produced the best results from the standpoint of bead appearance and control of welding parameters. In addition, the MIG weldments, though acceptable according to the inspection procedures employed, exhibited a larger number of defects than did the TIG welds. In particular, a considerable amount of microporosity, undetected by radiographic inspection, was evident on examination of the fracture surfaces of the MIG weldments.

On the basis of both mechanical properties and general weldability, the results of this study indicate that the TIG process (using any of the three filler alloys included in the study) produces the optimum results in welding 0.50-inch X7106-T63 plate. Since only slight differences were observed between the TIG square-butt and the TIG double-V weldments, the square-butt joint is the most suitable of the two due to the relative simplicity of joint preparation.

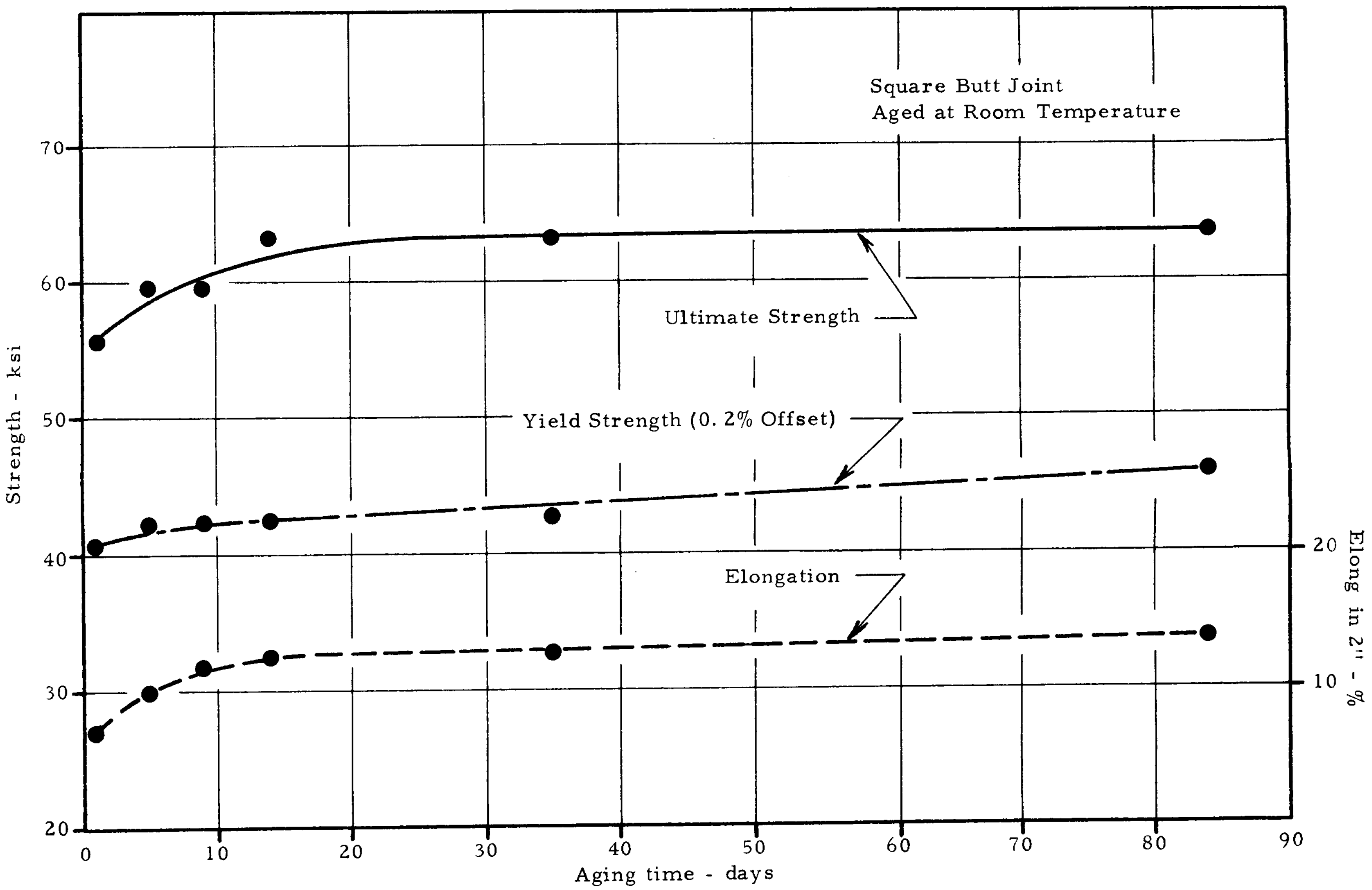


FIGURE C-3. TENSILE PROPERTIES OF 0.50-INCH TIG X7106-T63/X5180 WELDMENTS (Aging Characteristics Typical of 0.50-Inch Weldments Included in Study.)

TABLE C-4. SUMMARY OF TENSILE PROPERTIES OF 0.50-INCH TIG-X7106 WELDMENTS

Weldment Type	Panel No.	Aging Time	Yield Strength(1)				Ultimate Strength				Elongation in 2 in.	
			No. of Tests	Avg. ksi	S_y(2) ksi	LTL(3) ksi	No. of Tests	Avg. ksi	S_u(2) ksi	LTL(3) ksi	Avg. %	S_e(2) %
TIG-X7106 X5180 Sq. Butt	CT3-2	1 day	4	26.8	0.19	26.6	5	45.8	0.28	44.2	10.7	0.63
		5 days	4	29.9	0.67	29.3	5	49.9	0.96	44.4	12.2	1.42
		9 days	5	31.7	0.37	29.5	5	49.8	1.56	40.8	12.0	1.84
		2 weeks	4	32.1	0.33	31.7	4	53.3	1.50	51.2	12.5	0.93
		5 weeks	5	34.6	0.27	33.0	5	53.3	0.44	50.8	11.6	2.37
		12 weeks	5	35.8	0.48	33.0	5	53.5	0.94	48.0	13.1	0.57
TIG-X7106 5356 Sq. Butt	CT4-2	1 day	6	26.3	0.45	24.1	6	45.1	0.58	42.2	9.1	1.36
		5 days	6	30.0	0.64	26.8	6	48.7	0.37	46.8	9.8	0.72
		9 days	6	30.6	0.29	29.2	6	49.7	0.67	46.3	10.9	2.17
		2 weeks	6	31.8	0.34	30.0	6	51.0	0.34	49.2	10.9	1.71
		5 weeks	6	33.2	0.66	29.9	6	52.6	0.24	51.4	12.7	0.74
		12 weeks	6	35.1	0.27	33.7	6	53.0	0.65	49.7	12.7	0.78
TIG-X7106 5556 Sq. Butt	CT5-6	1 day	6	26.8	0.61	23.7	6	45.4	0.78	41.4	8.9	0.72
		5 days	6	30.3	0.25	29.1	6	48.8	0.74	45.1	9.4	0.55
		9 days	6	30.3	0.40	28.3	6	49.1	0.39	47.1	9.8	0.62
		2 weeks	6	30.8	0.39	28.8	6	49.5	1.19	43.5	10.8	1.94
		5 weeks	6	34.1	1.08	28.7	5	53.2	0.85	48.3	11.5	2.07
		12 weeks	6	35.0	0.46	32.7	6	53.2	1.14	48.7	11.1	1.14

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)

TABLE C-4. SUMMARY OF TENSILE PROPERTIES OF 0.50-INCH TIG-X7106 WELDMENTS (Cont'd)

Weldment Type	Panel No.	Aging Time	Yield Strength(1)				Ultimate Strength				Elongation in 2 in.	
			No. of Tests	Avg. ksi	S_y(2) ksi	LTL(3) ksi	No. of Tests	Avg. ksi	S_u(2) ksi	LTL(3) ksi	Avg. %	S_e(2) %
TIG-X7106 X5180 Double V	CT3-4	3 days	6	28.9	0.85	24.6	6	47.8	0.54	45.0	8.9	0.73
		5 days	6	30.5	0.33	28.8	6	49.6	0.43	47.4	8.7	0.34
		10 days	6	34.1	0.51	31.6	6	52.0	0.37	50.1	8.7	0.34
		17 days	6	34.6	1.07	29.2	6	52.5	0.24	51.2	9.2	0.39
		5 weeks	6	34.4	0.46	32.1	6	52.6	0.27	51.2	9.3	0.77
		12 weeks	6	35.2	0.94	30.4	6	52.8	0.60	49.8	9.4	1.18
TIG-X7106 5356 Double V	CT4-4	3 days	6	28.6	0.35	26.8	6	47.7	0.43	45.5	8.9	0.73
		5 days	6	30.3	1.01	25.1	6	48.8	0.46	46.5	8.7	0.56
		10 days	6	33.8	1.42	26.6	6	51.0	0.31	49.4	9.5	0.43
		17 days	6	34.1	0.48	31.7	6	51.5	0.62	48.3	9.7	0.44
		5 weeks	6	32.8	0.51	30.2	6	52.0	0.34	50.2	9.4	0.79
		12 weeks	6	34.2	0.50	31.7	6	52.4	0.45	50.2	9.7	0.43
TIG-X7106 5556 Double V	CT5-8	3 days	6	28.5	0.50	26.0	6	48.1	0.58	45.1	8.7	0.77
		5 days	6	29.8	0.42	27.7	6	49.5	0.23	48.3	8.7	0.32
		10 days	6	33.6	0.40	31.6	6	51.3	0.39	49.4	9.8	0.99
		17 days	6	34.4	0.27	33.0	6	51.5	0.48	49.1	9.6	0.20
		5 weeks	6	32.6	0.57	30.0	6	51.9	0.52	49.3	9.1	0.81
		12 weeks	6	33.5	0.68	30.1	6	52.6	0.91	48.0	9.4	0.86

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)

TABLE C-5. SUMMARY OF TENSILE PROPERTIES OF 0.50-INCH MIG-X7106 WELDMENTS

Weldment Type	Panel No.	Aging Time	Yield Strength[1]				Ultimate Strength				Elongation in 2 in.	
			No. of Tests	Avg. ksi	S_y[2] ksi	LTL[3] ksi	No. of Tests	Avg. ksi	S_u[2] ksi	LTL[3] ksi	Avg. %	S_e[2] %
MIG-X7106 X5180 Double V	CM3-2	1 day	6	26.4	0.69	22.9	6	44.8	1.11	39.2	9.5	1.30
		4 days	6	30.5	2.78	16.5	6	46.9	0.83	42.7	8.6	0.99
		1 week	6	30.7	0.29	29.2	6	47.3	2.84	33.0	8.0	1.60
		2 weeks	6	31.6	0.35	29.8	6	50.3	1.08	44.9	8.3	0.95
		5 weeks	6	32.5	0.41	30.4	6	51.2	1.25	44.8	8.7	1.81
		12 weeks	6	34.8	0.55	32.1	6	52.2	1.80	43.1	8.0	1.41
MIG-X7106 5356 Double V	CM4-2	1 day	6	24.1	0.47	21.7	7	44.3	0.64	41.4	9.0	0.49
		4 days	6	25.5	0.88	21.1	6	45.7	1.23	39.5	9.0	1.13
		1 week	6	26.1	0.68	22.6	6	47.4	1.00	42.3	8.2	0.85
		2 weeks	6	27.0	0.81	22.8	6	48.4	0.50	45.9	8.4	0.56
		5 weeks	6	28.1	0.49	25.6	6	48.7	1.46	41.3	7.1	0.63
		12 weeks	6	29.7	0.45	27.4	6	50.2	0.75	46.4	7.5	0.81
MIG-X7106 5556 Double V	CM5-1	1 day	6	28.7	0.63	25.5	6	43.8	1.62	35.6	8.5	.84
		6 days	6	31.6	0.53	28.9	7	46.9	1.50	39.9	7.8	1.77
		9 days	6	32.3	0.29	30.9	6	48.0	0.81	43.9	7.9	0.30
		2 weeks	6	32.7	0.70	29.2	6	48.3	0.89	43.8	8.1	1.00
		5 weeks	6	31.0	0.61	27.9	6	49.7	1.14	43.9	6.8	0.96
		12 weeks	6	36.7	0.44	34.4	6	51.9	1.28	45.4	8.1	1.10

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)

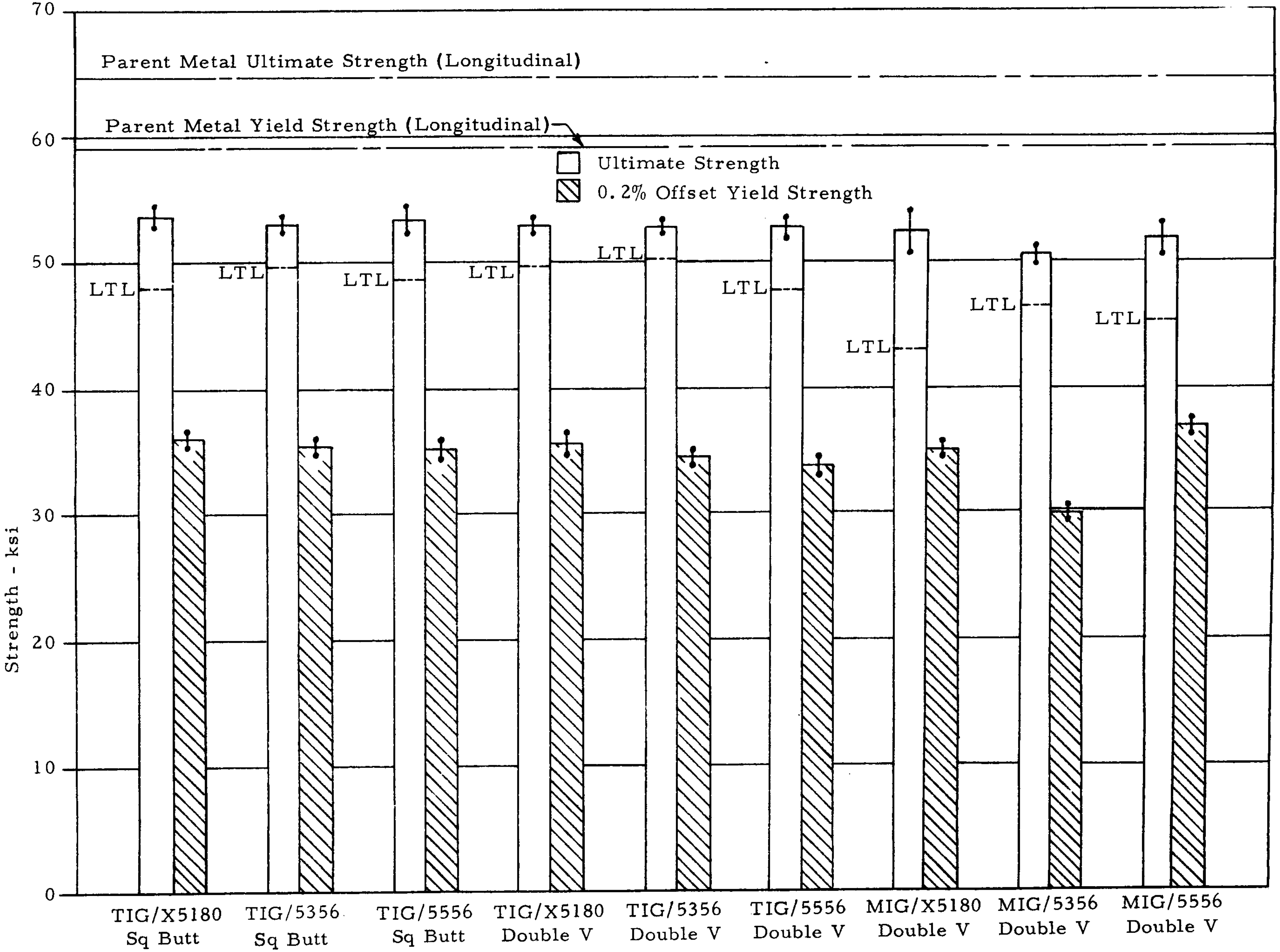


FIGURE C-4. TENSILE PROPERTIES OF 0.50-INCH TIG AND MIG X7106-T63 WELDMENTS AGED TWELVE WEEKS (Parent Metal Data from Ref. 4.)

3. 1.00-Inch X7106-T63 Weldments

The study of the aging characteristics of 1.00-inch X7106-T63 weldments was conducted on panels fabricated by the MIG and TIG processes using X5180, 5356, and 5556 filler alloys. A double-V joint configuration was employed for all test panels in this portion of the program.

In general, the 1.00-inch weldments exhibited less significant increases in strength than did the thinner materials. Increases in ultimate strength of up to approximately 14 percent were noted for this group. Typical aging data for the 1.00-inch weldments prepared by each of the two processes (TIG and MIG) are shown in Figure C-5.

The tensile properties, as a function of aging time, are summarized in Tables C-6 and C-7 and the average tensile properties after an aging period of 12 weeks are presented in Figure C-6.

Figure C-6 presents the average tensile properties of the 1.00-inch weldments after an aging period of 12 weeks. The TIG weldments, as a group, exhibited average ultimate strengths higher than those of the MIG weldments (48.2 to 52.8 ksi for TIG weldments as compared to 44.2 to 47.7 ksi for MIG weldments). The average ultimate strength of the TIG/5556 weldments (52.8 ksi) was significantly higher than that of any of the MIG weldments. Among the TIG welds, those made with 5556 filler alloy also exhibited the highest value of average yield strength (38.5 ksi). In general, the various MIG weldments exhibited yield strengths either comparable to or slightly higher than those of the TIG weldments.

In welding the 1.00-inch test panels, the TIG process again produced the best results when judged by bead appearance and ease of control. This fact, coupled with the mechanical properties of the various weldments, clearly indicates that of the processes investigated, the TIG process utilizing filler alloy 5556 produces the optimum results for this thickness. It should be noted that the 1.00-inch weldments represent the only case where significant differences were noted between the mechanical properties of weldments prepared by the TIG process and those prepared by the MIG process.

B. Tensile Test Failure Location

In the previous study of the aging characteristics of 0.090-inch X7106-T63 weldments(4), it was observed that after aging periods of one week or longer the majority of tensile specimens in any group failed in the heat-affected base metal rather than in the weld metal. This observation indicated that natural aging resulted in a weld deposit (crown intact) with a higher ultimate strength than the adjoining heat-affected base metal where some

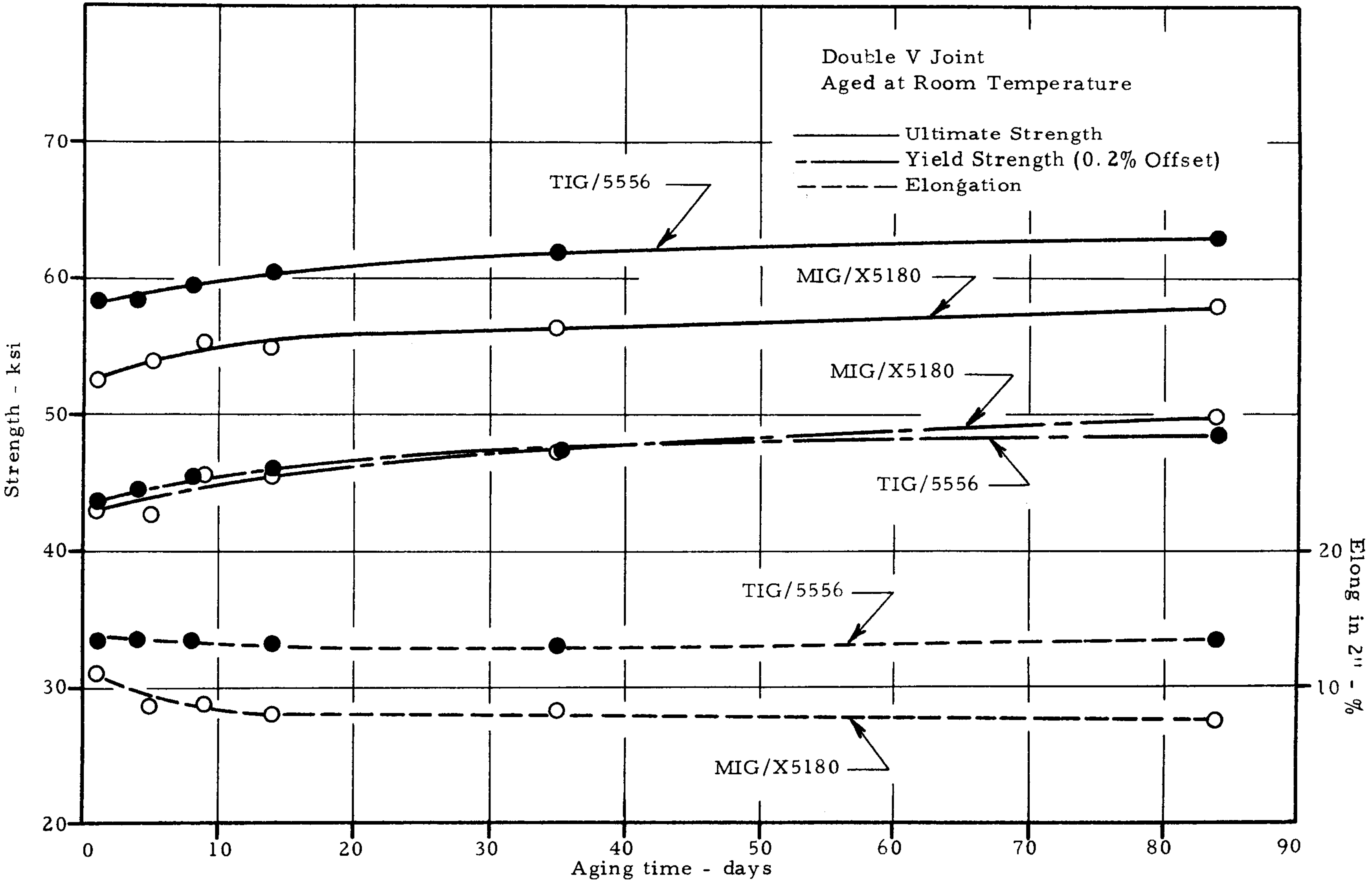


FIGURE C-5. TENSILE PROPERTIES OF 1.00-INCH TIG AND MIG X7106-T63 WELDMENTS (Aging Characteristics Typical of 1.00-Inch Weldments Included in Study.)

TABLE C-6. SUMMARY OF TENSILE PROPERTIES OF 1.00-INCH TIG-X7106 WELDMENTS

Weldment Type	Panel No.	Aging Time	Yield Strength(1)				Ultimate Strength				Elongation in 2 in.	
			No. of Tests	Avg. ksi	S_y(2) ksi	LTL(3) ksi	No. of Tests	Avg. ksi	S_u(2) ksi	LTL(3) ksi	Avg. %	S_e(2) %
TIG-X7106 X5180 Double V	CT3-3	1 day	6	30.2	0.83	26.0	3	44.3	2.17	(4)	16.6	0.60
		4 days	6	32.0	0.95	27.2	3	46.5	0.66	(4)	13.5	(5)
		8 days	6	33.2	1.22	27.1	3	46.9	1.18	(4)	15.3	(6)
		2 weeks	6	34.4	0.83	30.2	3	47.5	1.27	(4)	16.7	(6)
		5 weeks	6	34.4	0.59	31.4	3	47.8	0.93	(4)	(7)	
		12 weeks	6	35.6	1.20	29.5	3	48.2	1.07	(4)	(7)	
TIG-X7106 5356 Double V	CT4-3	36 hours	6	31.4	0.77	27.6	5	46.1	0.52	43.1	14.9	0.49
		5 days	6	32.7	0.46	30.4	5	46.8	0.65	43.0	14.3	1.71
		9 days	6	34.0	0.20	33.0	6	47.6	0.93	42.9	14.4	1.68
		2 weeks	5	34.7	0.11	34.0	6	48.8	0.99	43.8	15.1	1.46
		5 weeks	6	36.0	0.23	34.7	6	49.8	0.79	45.8	14.1	1.27
		12 weeks	6	37.0	0.45	34.8	6	51.4	0.82	47.2	14.3	0.43
TIG-X7106 5556 Double V	CT5-7	36 hours	6	33.4	0.22	32.3	5	48.3	0.46	45.6	14.6	0.48
		5 days	6	34.4	0.73	30.7	5	48.4	0.37	46.3	14.2	0.69
		9 days	6	35.4	0.32	33.7	5	49.6	0.32	47.8	13.5	0.46
		2 weeks	6	35.9	0.38	33.9	5	50.5	0.21	49.3	13.4	0.67
		5 weeks	6	37.3	0.48	34.9	6	51.9	0.44	49.4	13.1	0.99
		12 weeks	6	38.5	0.51	36.0	6	52.8	0.54	50.1	13.8	0.51

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)
(4) Insufficient data for specification of LTL of Ultimate Strength
(5) Data from two tests
(6) Data from one test
(7) No elongation data obtained from tests

TABLE C-7. SUMMARY OF TENSILE PROPERTIES OF 1.00-INCH MIG-X7106 WELDMENTS

Weldment Type	Panel No.	Aging Time	Yield Strength(1) No. of Tests	Yield Strength(1) Avg. ksi	Yield Strength(1) S_y(2) ksi	Yield Strength(1) LTL(3) ksi	Ultimate Strength No. of Tests	Ultimate Strength Avg. ksi	Ultimate Strength S_u(2) ksi	Ultimate Strength LTL(3) ksi	Elongation in 2 in. Avg. %	Elongation in 2 in. S_e(2) %
MIG-X7106 X5180 Double V	CM3-3	1 day	6	32.7	1.52	25.0	6	42.1	0.44	39.9	11.0	0.80
		5 days	6	32.5	1.53	24.7	6	43.7	0.49	41.2	8.6	0.82
		9 days	6	35.5	0.29	34.0	6	45.0	0.94	40.2	8.9	0.59
		2 weeks	6	35.2	0.34	33.5	6	44.7	0.99	39.7	7.7	0.59
		5 weeks	6	37.1	0.63	33.9	6	46.3	0.41	44.2	8.2	0.84
		12 weeks	6	39.8	0.43	37.6	6	47.7	0.83	43.5	7.3	0.81
MIG-X7106 5356 Double V	CM4-3	1 day	6	31.4	0.56	28.5	6	41.3	0.84	37.1	9.6	0.24
		4 days	6	32.0	1.18	26.0	6	41.5	0.52	38.8	8.7	0.54
		7 days	5	33.4	0.29	31.7	6	41.6	0.84	37.4	8.6	0.37
		2 weeks	6	33.0	0.52	30.4	6	42.4	0.82	38.2	7.5	0.55
		5 weeks	6	34.2	0.47	31.8	6	42.9	0.41	40.8	8.2	0.58
		12 weeks	6	37.0	0.32	35.4	6	44.2	0.28	42.8	7.2	0.61
MIG-X7106 5556 Double V	CM5-4	1 day	6	32.4	0.12	31.8	6	44.3	1.56	36.4	11.0	0.71
		4 days	6	35.2	0.54	32.4	6	44.4	2.05	34.1	10.0	1.03
		7 days	5	34.8	0.13	34.0	6	44.5	1.46	37.1	8.9	0.43
		2 weeks	6	35.3	0.39	33.3	6	45.2	1.29	38.7	8.1	0.84
		5 weeks	6	36.4	0.33	34.7	6	45.4	1.11	39.8	8.8	0.91
		12 weeks	6	38.6	0.34	36.9	6	45.6	1.70	37.0	8.2	1.26

(1) 0.2% Offset
(2) Standard Deviation
(3) 99% Lower Tolerance Limit (95% Confidence)

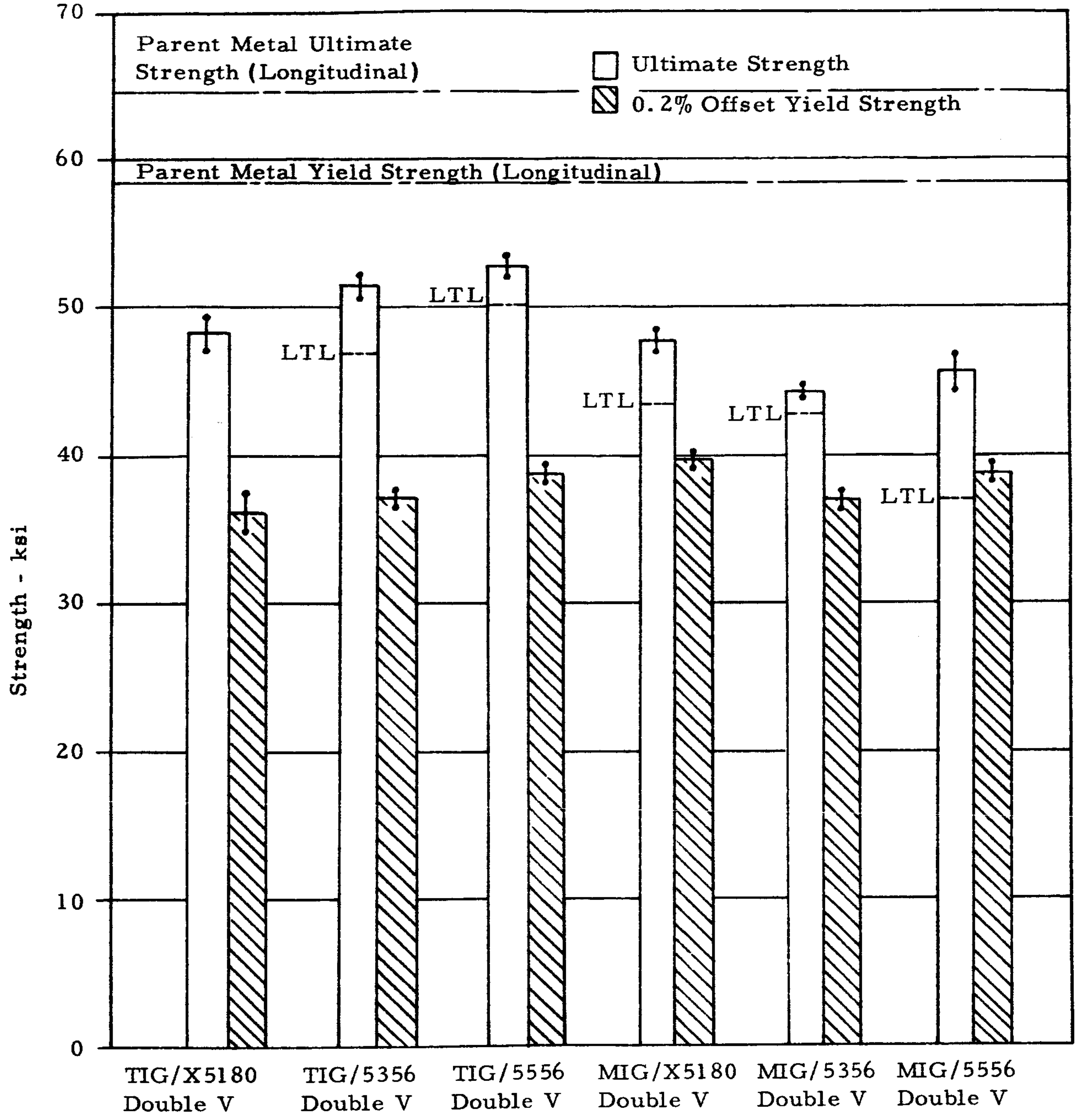


FIGURE C-6. TENSILE PROPERTIES OF 1.00-INCH TIG AND MIG X7106-T63 WELDMENTS AGED TWELVE WEEKS (Parent Metal Data from Ref. 4.)

degree of overaging occurs. As a result of these previous observations, particular attention was directed to the location of failures of the tensile specimens tested in this program.

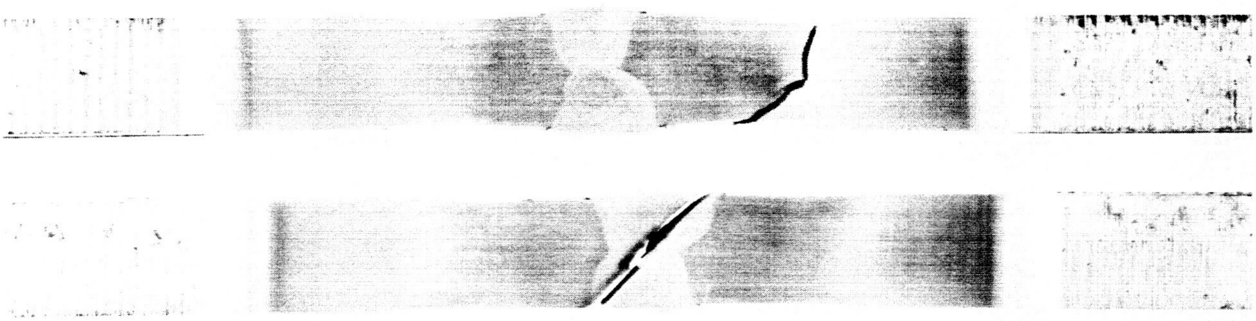
In the present study, the majority of the weldments tested failed in the weld deposit or at the fusion line for all aging periods (12 weeks maximum). A shift in failure location from the weld deposit (or fusion line) to the heat-affected base metal with increasing aging time was observed only in the case of the 0.50-inch TIG square-butt and 1.00-inch TIG double-V weldments. The failure locations for the various weldments are summarized as follows:

Failure in Weld Deposit or at Fusion Line for All Aging Periods	Failure in HAZ after Aging
0.187-inch TIG square-butt	0.50-inch TIG square-butt
0.187-inch MIG square-butt	1.00-inch TIG double-V
0.50-inch TIG double-V	
0.50-inch MIG double-V	
1.00-inch MIG double-V	

In the cases where the failure location shifted from the weld deposit to the heat-affected base metal on aging, all specimens in one group (one weldment type and one aging time) did not necessarily fail in the same relative locations. However, in any case where one or more specimens in one group failed in the heat-affected zone, all specimens in that group exhibited extensive deformation in the heat-affected zone and cracks in the weld deposit. Evidently, in these cases, the strength of the weld deposit and the strength of the weakest portion of the heat-affected base metal were very nearly equal, and the actual failure location was dictated only by slight local variations in strength.

Two tensile specimens, representative of the two types of failure observed in the test series, are shown in Figure C-7. The two particular specimens were cut from the 0.50-inch TIG weldments made with 5356 filler wire, and represent aging periods of one day and 12 weeks. The shift of the location of the failure on aging is apparent.

The observed shift of the failure location in certain X7106-T63 weldments (both in the present study and in that of Contract NAS8-1529) is indicative of a condition in which the strength of the weld bead is not the controlling factor in determining the failure stress of a weldment. Apparently, the strength of the weld bead increases as a result of natural aging, to the point where the strength of the weld deposit, coupled with the additional cross-sectional area of the weld crown, exceeds the strength of the heat-affected



Tensile Specimens:

Upper specimen aged 12 weeks
Lower specimen aged 1 day

FIGURE C-7. 0.50-INCH TIG X7106-T63/5356 base metal, where some degree of overaging occurs. Such a condition would lead to a shift in the failure location as was noted in this study.

The observation of such a condition is consistent with similar observations made on 0.090-inch thick X7106-T63 weldments in the previous study. In addition, it has been established that a significant degree of overaging does occur in regions of the heat-affected base metal.(4)

As noted above, only certain weldment types exhibited the shift of failure location. This difference in aging characteristics may be associated with one of the following conditions:

(1) Differences in heat input and heat dissipation among the various combinations of material thickness, welding process and joint configuration could lead to variations in the quenching rate of the weld deposit and the degree of overaging in the heat-affected base metal.

(2) In the thicker materials, the zone of heat-affected base metal may extend beyond the limits of the tensile specimen test section.

(3) Differences in final bead configuration between the 0.090-inch weldments(4) and the 0.187-inch weldments would result in variations in the degree of dilution of the weld deposit. Such variations could lead to the observed differences in aging characteristics.

C. Crack Susceptibility of X7106-T63 Weldments

In a previous study of the characteristics of X7106 weldments (Contract NAS8-1529 Mod 6), some attention was directed toward the susceptibility of such weldments to hot cracking.(4) In that study, crack susceptibility tests were made on X7106-T63 and 2219-T87 weldments, employing Houldcroft test specimens.(10) The results of that study indicated that X7106 weldments were more susceptible to hot cracking than the 2219 weldments. In the present study, tests were performed utilizing a modified Houldcroft specimen, as described by Rogerson, et al.(11) This type of specimen is designed to provide uniformly decreasing restraint along the length of the weld and employs an integral run-on tab to stabilize heat flow. The test is performed by depositing a bead-on-plate weld down the centerline of the specimen. The length of the resulting crack, beyond the end of the run-on tab, is used as a measure of the crack susceptibility of a given parent metal-filler metal combination. The details of the test specimen design and the particular procedures employed in the tests are given in Appendix E.

In this portion of the program, crack susceptibility tests were performed on each of the following parent metal-filler metal combinations:

X7106-T63/X5180
X7106-T63/5356
X7106-T63/5556
2219-T87/2319
2014-T6/4043

The results of the crack susceptibility tests are listed in Table C-8 and presented graphically in Figure C-8. Typical examples of the test results, as indicated by radiographs of the test specimens, are shown in Figure C-9. As may be noted in Table C-8 and Figure C-8, the data from the tests on X7106-T63/5556 and 2219-T87/2319 specimens exhibited a higher degree of scatter than that of the other weldments. When the degree of scatter is taken into account, the results of these tests indicate that the degree of crack susceptibility for the X7106-T63 alloy is comparable to that of 2014-T6. In addition, the results indicate that both 2014-T6 and X7106-T63 weldments are significantly more susceptible to hot cracking than 2219-T87 weldments. It may be noted that the scatter in the crack length measurements on the 2219-T87 weldments is in the same order as the average crack length. It is felt that this high degree of scatter is associated with the fact that the welding parameters were selected to prevent complete cracking of the X7106-T63 weldments and resulted in very limited cracking in the 2219-T87 weldments.

In addition to the crack susceptibility tests performed on 0.125-inch sheet, as described above, some effort was directed toward a measurement of the crack susceptibility in thicker plates. For this purpose, two preliminary cruciform crack susceptibility tests were conducted on 0.50-inch X7106-T63 plate. One of these tests was made with a single-pass fillets, and the other with three-pass fillets. In both cases, X5180 filler wire was employed. Upon completion, each cruciform weldment was given a dye penetrant inspection. No cracks were detected in either of the weldments, indicating that this type of test is not suitable for application to aluminum weldments. As a result, no further crack susceptibility tests were performed on the thicker sections of X7106-T63 plate.

TABLE C-8. CRACK SUSCEPTIBILITY TEST RESULTS

(0.125-Inch Modified Houldcroft Test Specimens)

Parent Metal & Filler Metal	Individual Crack Lengths, inches	Mean Crack Length, inches	Standard Deviation, inches
2219-T87/2319	0.080, 0.660, 1.180 0.439, 0.161, 1.115	0.552	0.541
2014-T6/4043	1.464, 1.995, 2.125 1.318, 1.168, 1.833	1.659	0.394
X7106/X5180	1.880, 2.201, 1.617 1.730, 2.009, 1.612	1.840	0.235
X7106/5356	1.810, 1.725, 2.130 1.463, 2.069, 1.060	1.710	0.400
X7106/5556	0.750, 0.240, 1.742 1.936, 1.140, 2.245	1.341	0.765

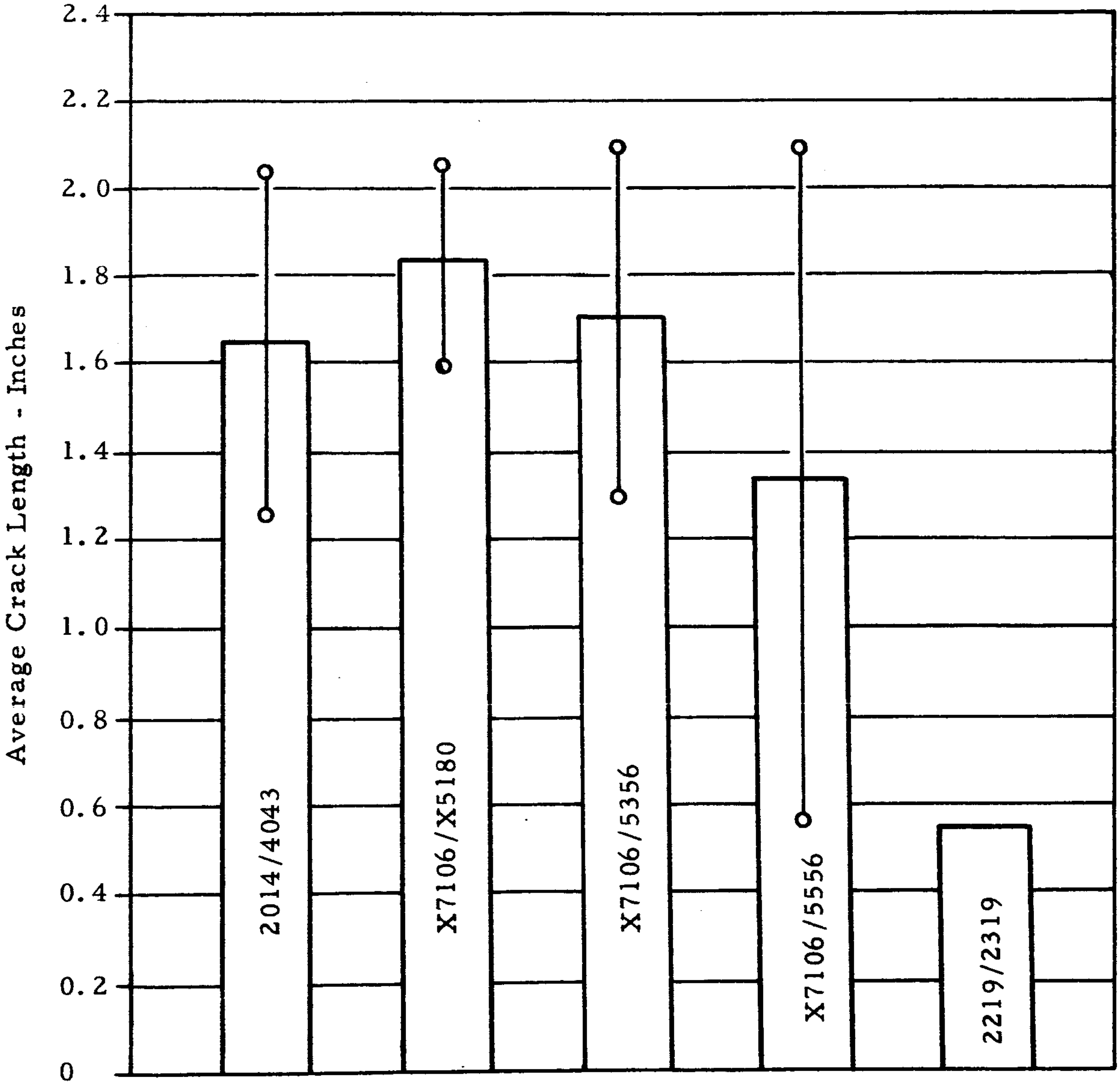
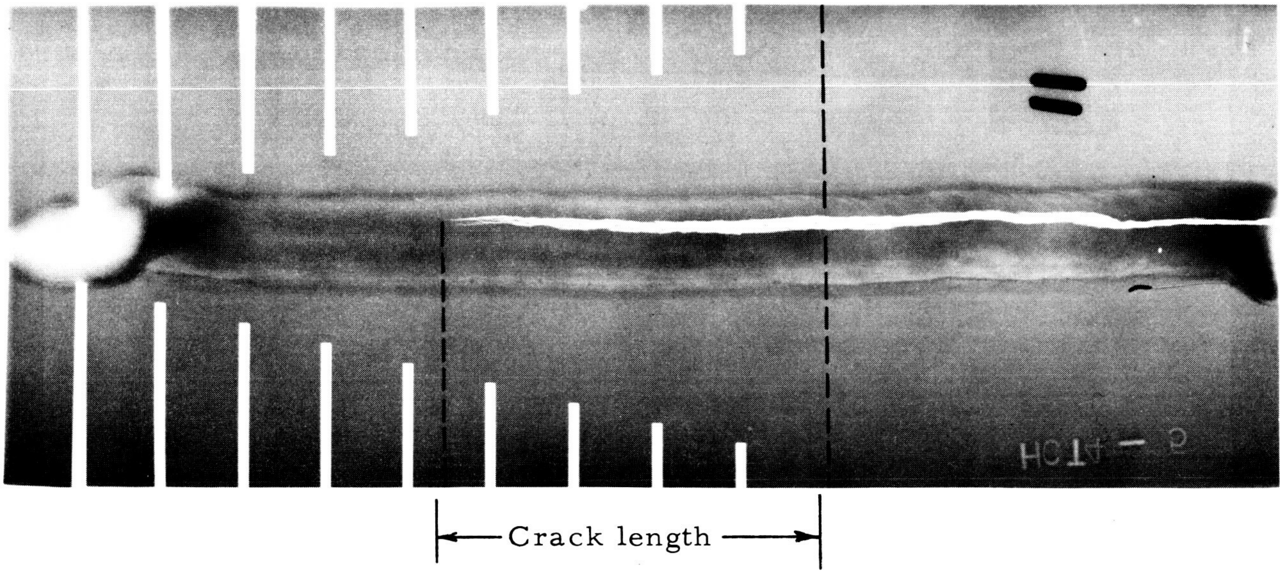
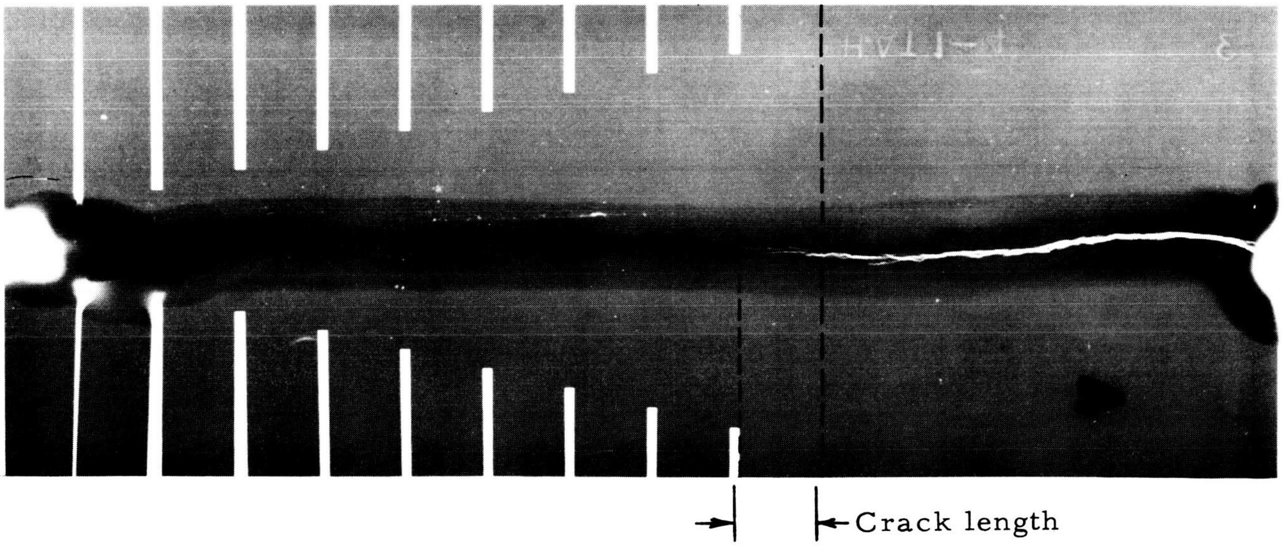


FIGURE C-8. AVERAGE CRACK LENGTHS MEASURED IN CRACK SUSCEPTIBILITY TESTS (0.125-Inch Modified Houldcroft Test Specimens)



(a) X7106-T63/5556



(b) 2219-T87/2319

FIGURE C-9. TYPICAL CRACK SUSCEPTIBILITY SPECIMENS AFTER COMPLETION OF TESTS

Prints from Radiographic Negatives

APPENDIX D

A SURVEY OF THE LITERATURE RELATED TO MECHANICAL PROPERTIES OF MATERIALS SUBJECTED TO BIAXIAL STRESSES

A SURVEY OF THE LITERATURE RELATED TO MECHANICAL PROPERTIES OF MATERIALS SUBJECTED TO BIAXIAL STRESSES

The biaxial properties of metals reported in the literature have been determined by a number of methods:

(1) Circular and elliptical bulge tests

(2) Burst tests on cylinders and spheres

(3) Tensile-cross tests

(4) Uniaxial tensile tests on very wide specimens

Each of these tests has advantages and disadvantages as far as material requirements, fabrication problems, and stress analyses are concerned. The object of this survey is not to evaluate the various methods; rather it is to gather information on the relationships between the biaxial and uniaxial properties determined by any of the methods.

The following overall generalizations can be drawn from the data in the literature:

(1) For 1:1 biaxial loading, the yield and ultimate strengths are approximated by the corresponding uniaxial properties. The ductility is lower under biaxial loading conditions than under uniaxial loading conditions.

(2) For 2:1 biaxial loading, the yield strengths are greater than the 1:1 biaxial and the corresponding uniaxial properties. The ultimate strengths are generally equal to or greater than the uniaxial ultimate strengths. The ductility under biaxial conditions is generally lower than the uniaxial ductility.

(3) There appears to be no general dependence of the biaxial/uniaxial strength ratio on the strength level of the material. In the case of very high strength alloys, however, reduced biaxial strengths have been reported.

Baird(12) reported results on welded cylinders of a number of high-strength ferrous alloys. For 4340 steel, quenched and tempered to four strength levels, he reported the following approximate average results:

Tempering Temperature (°F)	Uniaxial Yield Strength (ksi)	2:1 Biaxial Yield Strength (ksi)	Biaxial/ Uniaxial Ratio
425	205	241	1.17
700	194	218	1.12
900	170	188	1.11
Annealed	88	93	1.06

For Vascojet 1000, at three strength levels, he obtained the following:

Tempering Temperature (°F)	Uniaxial Yield Strength (ksi)	2:1 Biaxial Yield Strength (ksi)	Biaxial/ Uniaxial Ratio
975	252	(a)	-
1050	246	266	1.08
1100	205	262	1.28

(a) Failed before reaching yield strength.

For D6AC, heat treated to two strength levels, he obtained:

Tempering Temperature (°F)	Uniaxial Yield Strength (ksi)	2:1 Biaxial Yield Strength (ksi)	Biaxial/ Uniaxial Ratio
600	229	(a)	-
800	221	259	1.17

(a) Failed before reaching yield strength.

For PH15-7 Mo, at three strength levels, he reported the following:

Condition	Uniaxial Yield Strength (ksi)	2:1 Biaxial Yield Strength (ksi)	Biaxial/ Uniaxial Ratio
RH-950	212	(a)	-
TH-1050	198	196(b)	0.99
TH-1100	192	226(c)	1.18
TH-1100	192	216(b)	1.13

(a) Failed before yielding.
(b) Weld metal yield strength.
(c) Parent metal yield strength.

For all these materials, the yield strength was higher under 2:1 biaxial loading than under uniaxial loading and was unaffected by strength level.

McClaren and Best(13) reported data obtained on both ferrous and non-ferrous alloys using the tensile-cross type specimen. They did not report yield strength data for the biaxial tests. The following table summarizes ultimate strength results:

Alloy	Orientation	Uniaxial UTS (ksi)	1:1 Biaxial		2:1 Biaxial	
			UTS	Ratio	UTS	Ratio
6A-4V Ti	L	162	168	1.04	197	1.22
	T	169	172	1.02	202	1.20
Type 301 Stainless	L	196	201	1.03	227	1.16
	T	203	201	0.99	236	1.16
AM 355	L	228	231	1.01	259	1.14
	T	231	230	0.99	267	1.15
Maraging Steel (300 Grade)	L	301	313	1.04	348	1.16
	T	320	312	0.98	-	-

Essentially, the 1:1 biaxial strength was equal to the uniaxial ultimate strength and the 2:1 biaxial strength was approximately 15% greater than the uniaxial ultimate strength.

Marin(5) performed biaxial tests on a tubular specimen of 24S-T aluminum alloy. The uniaxial, 1:1 and 2:1 data which he reported (yield, ultimate, and elongation) are summarized below:

BIAXIAL YIELD STRESS

Stress Ratio	Max Principal Stress	Biaxial/Uniaxial Ratio
Uniaxial	47.5	-
2:1	54.7	1.15
1:1	49.7	1.04

BIAXIAL ULTIMATE STRESS

Stress Ratio	Max Principal Stress	Biaxial/Uniaxial Ratio
Uniaxial	62.5	-
2:1	61.7	0.99
1:1	62.5	1.00

BIAXIAL DUCTILITY

Stress Ratio	Nominal (in. /in.)	True (in. /in.)
Uniaxial	0.146	0.136
1:1	0.075	0.074
2:1	0.062	0.060

McClaren and Terry(14) presented data on both parent and welded specimens of ferrous and nonferrous alloys using the tensile-cross specimens. The following ultimate strength results were obtained:

Alloy	Condition	Uniaxial UTS (ksi)	1:1 Biaxial		2:1 Biaxial	
			UTS	Ratio	UTS	Ratio
2014-T6	Parent	71.6	64.0	0.90	78.1	1.09
	Welded	46.2	-	-	-	-
B120 VCA	Parent	184.	180.5	0.98	228.3	1.24
	Welded	160.	-	-	-	-
5 Cr Mo V	Parent	275.	256.8	0.93	328.0	1.19
	Welded	278.	304.7	1.10	315.5*	1.13
D6AC	Parent	274.	249.5	0.91	-	-
	Welded	-	-	-	-	-
X 200	Parent	282.	240.6	0.85	335.	1.19
	Welded	-	-	-	-	-

*Data obtained from cylindrical pressure vessel.

The following ductility data were also presented:

Alloy	Condition	Uniaxial	1:1 Biaxial	2:1 Biaxial
2014-T6	Parent	8.2%	3.04%	4.30%
	Welded	6.0%	-	-
B120 VCA	Parent	7.1%	2.15%	2.30%
	Welded	7.0%	-	-
5 Cr Mo V	Parent	8.1%	3.12%	5.12%
	Welded	4.6%	2.61%	1.60%

The above data again indicate that the 2:1 biaxial ultimate strength exceeds the uniaxial results. However, the 1:1 biaxial ultimate strength appears to be somewhat less than the uniaxial ultimate strength. Under conditions of biaxial loading, the ductility is reduced in every case.

Robinson, et al.,(7) using the circular bulge test on several aluminum alloys, report the biaxial ultimate strength to be equal to the uniaxial ultimate strength. However, the data from this investigation are presented only in graphical form.

Corrigan, et al.,(15) performed biaxial tests on parent and welded alloys by employing a very wide tensile specimen with a transverse machined groove. Stress analysis showed that 2:1 biaxiality was obtained in the reduced section after yielding. The following results were reported:

Alloy	Orientation	Condition	Uniaxial		2:1 Biaxial	
			YS	UTS	UTS	Ratio
Tricent	L	Parent	200	221	248	1.12
"	T	Parent	207	224	252	1.13
"	T	Tungsten Arc	200	219	241	1.10
"	T	Metal Arc	197	208	224	1.08
"	L	Annealed Parent	86.5	108	122	1.13
D6AC	L	Parent	211	227	258	1.14
"	T	Parent	214	233	267	1.15
"	T	Tungsten Arc	208	225	254	1.13
H11	L	Parent	191	267	357	1.34
4335	L	Parent	-	263	314	1.19

These results also indicate that the ultimate strength of a material is higher under conditions of 2:1 biaxiality than under uniaxial loading.

Jaeger(16) lists a number of criteria for failure by either fracture or flow as follows:

(1) Maximum principal stress

(2) Maximum principal strain

(3) Maximum strain energy

(4) Maximum shear strain

(5) Maximum shear stress

(6) Maximum distortional strain energy

(7) Maximum conserved distortional strain energy

For failure by flow (yielding), the last three appear to fit the experimental observations the best, but, for failure by fracture, none of the theories are completely adequate. A brief description of these and the octahedral shear stress theory follows.

The maximum principal stress theory predicts failure will occur at a point under any condition of loading when the maximum principal stress at the point reaches the value of the critical stress determined from the uniaxial test. In other words, according to this theory, both the 1:1 and 2:1 biaxial strengths should be equal to the uniaxial strength.

The maximum prinicpal strain theory predicts failure will occur when the maximum principal strain reaches the value of limiting strain, as determined from the uniaxial test. In terms of principal stresses, this theory predicts that in tension-tension or compression-compression, the 1:1 biaxial strength is greater than the 2:1 biaxial strength which in turn is greater than the uniaxial strength.

The maximum strain energy theory predicts failure will occur at a point when the value of the strain energy per unit volume in the material at the point equals the maximum value of the strain energy per unit volume that the material can absorb in simple tension. In terms of principal stresses this reduces to

$$\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2 = \sigma_u^2$$

which predicts that the 1:1 and 2:1 biaxial strengths will be less than the uniaxial strength.

The maximum shear stress theory predicts that failure will occur when the maximum shear stress reaches the critical value determined in uniaxial tension. In the tension-tension or compresssion-compression quadrants, this theory leads to the same results as the maximum stress theory. They differ, however, in the two tension-compression quadrants.

The maximum distortion energy theory (Henchy-von Mises theory) predicts that failure will occur when the energy of distortion equals the energy of distortion that the material can absorb under simple tension. This theory can be expressed as

$$\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2 = \sigma_u^2$$

For 1:1 biaxial loading, this theory predicts that the biaxial strength will equal the uniaxial strength. For 2:1 biaxial loading, this theory predicts that the biaxial strength will be 1.15 times the uniaxial strength.

The maximum conserved distortional energy theory modified the above theory by taking into account the strain hardening coefficient of the material. It reduces to the above theory when the strain hardening coefficient is zero. When the strain hardening coefficient is greater than zero, the predicted biaxial strengths are reduced.

The octahedral shear stress theory predicts failure will occur when a stress invariant (related to the intensity of the shear stress) reaches some maximum value. This theory leads to

$$\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2 = \sigma_u^2$$

which is identical to the expression developed by the maximum distortion energy theory.

In summary, the work of Baird(12) and Marin(5) indicates that the biaxial yield strength follows the maximum distortion energy theory. The data presented by McClaren and Best(13), McClaren and Terry(14), and Corrigan, et al., (15) indicate that the biaxial ultimate strength can also be predicted by the maximum distortion energy theory, while the ultimate strength data reported by Marin(5) correlate better with the maximum stress theory. The results of Robinson(7) can be expressed by either of the above theories since in the special case of 1:1 biaxiality both theories coincide.

In addition to the references included in the foregoing discussion, several other publications were also reviewed in the literature survey. These additional publications are included in the List of References(17-25) to provide a more complete compilation of published data related to the mechanical properties of materials subjected to biaxial loading conditions.

APPENDIX E

EXPERIMENTAL PROCEDURES
(CONTRACT NAS8-20160)

EXPERIMENTAL PROCEDURES
(CONTRACT NAS8-20160)

A. Tensile Tests and Hardness Measurements

A standard uniaxial tensile test specimen, illustrated in Figure E-1, was used to generate the uniaxial tensile data for both parent metal and weldments in all portions of the program. Parent metal specimens were removed from the test panels with the axis of each specimen parallel to the rolling direction unless otherwise noted. Weldment specimens were machined from the test panels, with the specimen perpendicular to the weld, so that the weld was located in the center of the reduced section.

The tensile tests were performed on either a Baldwin 200,000-pound hydraulic tensile machine or on a 10,000-pound Instron testing machine. An LVDT extensometer with a two-inch gage length was utilized to generate the stress-strain curves in each case. A crosshead speed of 0.05 in./min was used in all tests. Yield strength (0.2% offset in 2 inches), ultimate tensile strength and elongation (in two inches) were recorded in each test.

B. Hydraulic Bulge Tests

The four types of parent metal bulge test panels which were used are illustrated in Figures E-2 through E-5. The machined parent metal panels of Figures E-3, E-4, and E-5 were designed to investigate methods of initiating fracture in the specimen prior to general yielding of the bulge panel. Such a condition was necessary in order that strain gage stress analysis could be used to determine the stress in the panel at failure.

The two types of welded panels which were employed are shown in Figures E-6 and E-7. The weld crown and drop-through on each specimen were left intact except for the two inches at each edge corresponding to the hold-down region of the test fixture.

The hydraulic bulge tests were run on either the circular die shown in Figure E-8 or the elliptical die shown in Figure E-9. In either case, the same test procedures were employed.

A schematic cross section, applicable to either of the hydraulic bulge test dies, is given in Figure E-10. The test specimen is clamped between the lower flat die and the upper die. The lower die is equipped with an inlet for hydraulic fluid and fittings to allow for connection of a relief valve and a pressure transducer. The lower edge of the opening in the upper die is machined to a radius of three inches to reduce the possibility of failure at the clamping edge. An O-ring in the lower die provides a seal for the pressurizing fluid.

The bulge height indicated in Figure E-10 was measured with a stainless steel deflectometer, shown in position in Figure E-8. The deflectometer was instrumented with a full strain gage bridge and readout was obtained with a Sanborn Model 311A indicator and a Sanborn Model 320 two-channel recorder. Immediately prior to each test, the deflectometer was calibrated with a series of standard test blocks.

The bulge test pressure was monitored with a strain-gage pressure transducer fabricated at SwRI. The complete transducer system consisted of a bourdon tube instrumented with a full strain gage bridge and the same type readout equipment that was used with the deflectometer. The transducer system was calibrated at the beginning of the test program by means of an Ashcroft deadweight tester. The results of this calibration are plotted in Figure E-11.

In the performance of each bulge test, the test panel was pressurized at a rate of approximately 50-75 psi per minute. Synchronous recordings of pressure and bulge height were made throughout the test until the specimen failed. From these data, the stress could be calculated by either of the formulas discussed in Appendix A:

$$\sigma_{mem} = \frac{PR}{2t}$$

or

$$\sigma = KP^{2/3}$$

C. Cylinder Tests

The configuration of the test specimens used in the cylinder burst tests is shown in Figure E-12. Each specimen consisted of a welded aluminum cylinder (17-5/8" OD × 1/8" wall × 23" long) riveted to a steel extension ring on each end. The extension rings were welded to standard pipe flanges. Standard blind flanges were modified as shown in the drawing to include an O-ring seal. A reinforcement plate, shown in Figure E-13, was cemented to the outside surface of the cylinders intended for parent metal studies. This patch, centered over the weld, was cemented on with Lefkoweld type 109 adhesive and type LM-52 activator.

After assembly, the specimen was installed in a Baldwin 200,000-pound universal testing machine, so that tensile and compressive loads could be superimposed on that resulting from internal pressurization. An X-Y recorder, which monitored a pressure cell measuring internal pressure and a load cell measuring axial load, was used to synchronize and record the two loadings during the test. Electrical resistance strain gage rosettes were cemented to the specimen to measure strain. Details of strain gage procedures are given in a later section of this appendix. A Gilmore multichannel X-Y recorder plotted strain at several locations as a function of the internal pressure (50-psi intervals) during the test. The pressure and load records were checked by visual readout bourdon tube pressure gages and the tensile machine load dial.

The pressure necessary to rupture the cylinder was used to calculate the biaxial ultimate strength by the standard thin-wall cylinder formulas.

D. LTV Biaxial Test

A biaxial test apparatus utilizing a cross-shaped sheet specimen has been developed by LTV-Vought Aeronautics Division. The equipment, procedures and test specimen are described in a recent report by McClaren and Foreman.(26) Briefly, a transverse load and an axial load are applied simultaneously to the test specimen. The transverse load is obtained with a floating frame separate from that applying the axial load so that no bending stresses are introduced as the specimen strains. The ratio of loads necessary to produce the desired stress ratio under elastic is determined with strain gages, then the load ratio so determined is continued to failure of the specimen.

Since extensive special test equipment is required for their performance, the tests were run at LTV-Vought Aeronautics Division in Dallas, Texas.

F. MIT Biaxial Test

The MIT biaxial test employs a wide tensile specimen with a transverse machined groove, as illustrated in Figure E-14. The biaxial stress condition is a result of the transverse restraint offered to the reduced section by the specimen geometry. Theoretically, the stress ratio reaches a value of 2:1 after the test section has reached a fully plastic condition.(27)

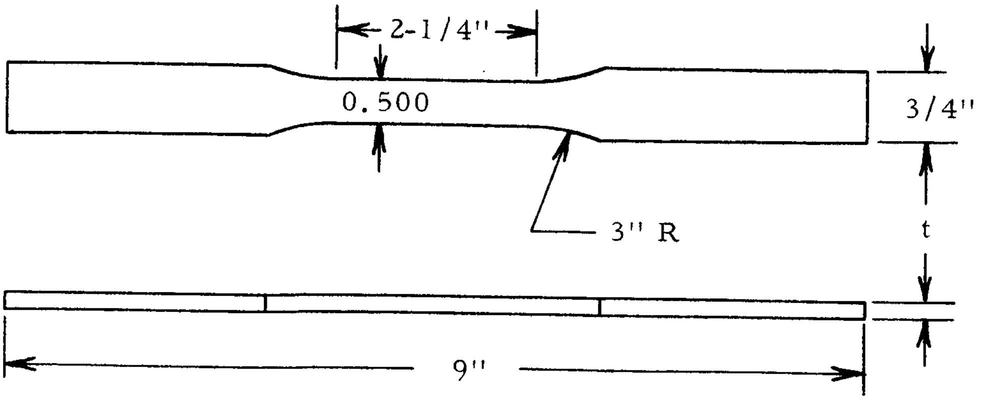
These tests were performed in an Instron testing machine in a manner similar to a conventional uniaxial tensile test. The biaxial strength is calculated from the maximum load and the initial cross-sectional area of the reduced section.

G. X7106-T63 Tensile Test Specimens

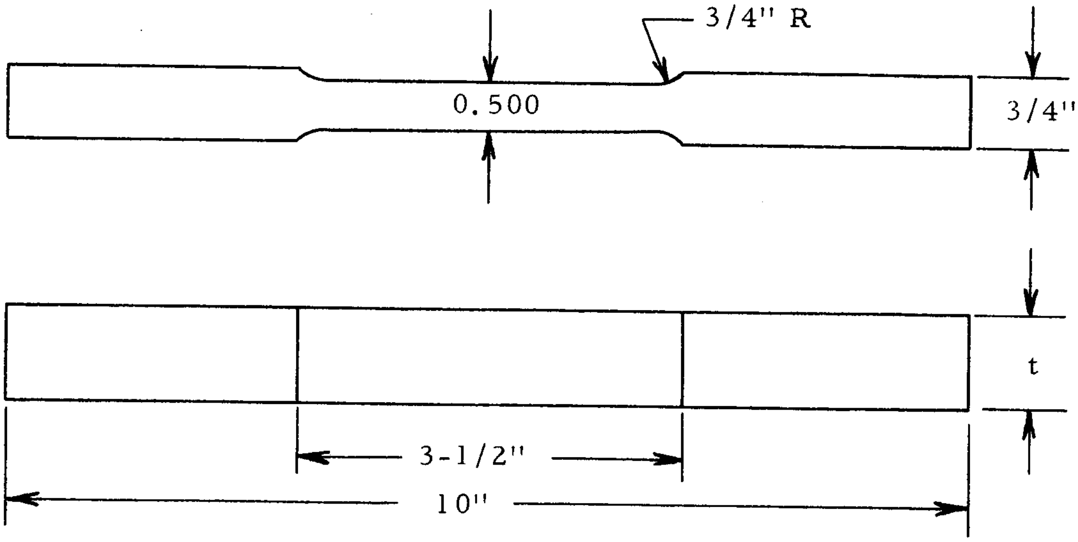
The uniaxial tensile test specimens utilized in the evaluation of the weldability of X7106-T63 were cut from welded panels fabricated for this specific purpose. These panels were fabricated by welding two 5-inch × 36-inch sections to form a 10-inch × 36-inch weldment. The welding processes, filler alloys and joint configurations employed are discussed in Appendix C, and the specific welding procedures utilized are listed as procedures 65A-2 through 65A-23 in Table F-1 of Appendix F. After welding, the panels were cut into tensile specimen blanks 3/4 inch wide and 10 inches long. These specimens were numbered sequentially according to their position in the panel. The finished specimens were tested in groups of six specimens each after selected aging periods. Each group was made up of specimens selected from locations approximately five inches apart, so that each test group contained specimens representative of the entire length of the weld.

H. Crack Susceptibility Tests

The crack susceptibility test performed in the portion of the program carried out under Contract NAS8-20160 utilized a modified Houldcroft specimen, illustrated in Figure E-15. The tests were performed by depositing a bead-on-plate weld down the centerline of the specimen. The welding procedures employed for this particular series of tests are listed in Table E-1. Upon completion of each test, radiographs of the test specimens were prepared, and the crack length in each case was measured from the indication on the radiograph.

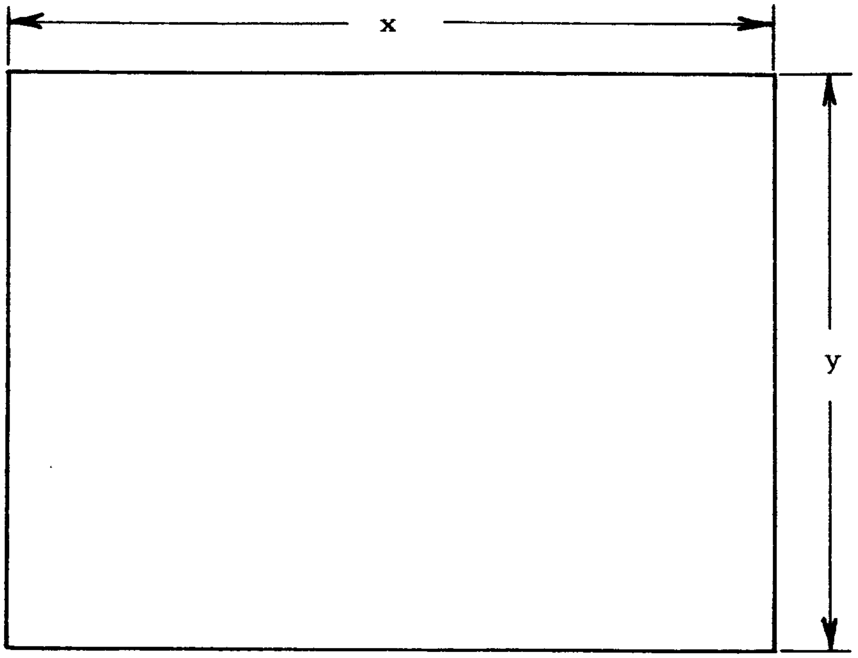


(a) 0.125-Inch and 0.187-Inch Sheet Specimen



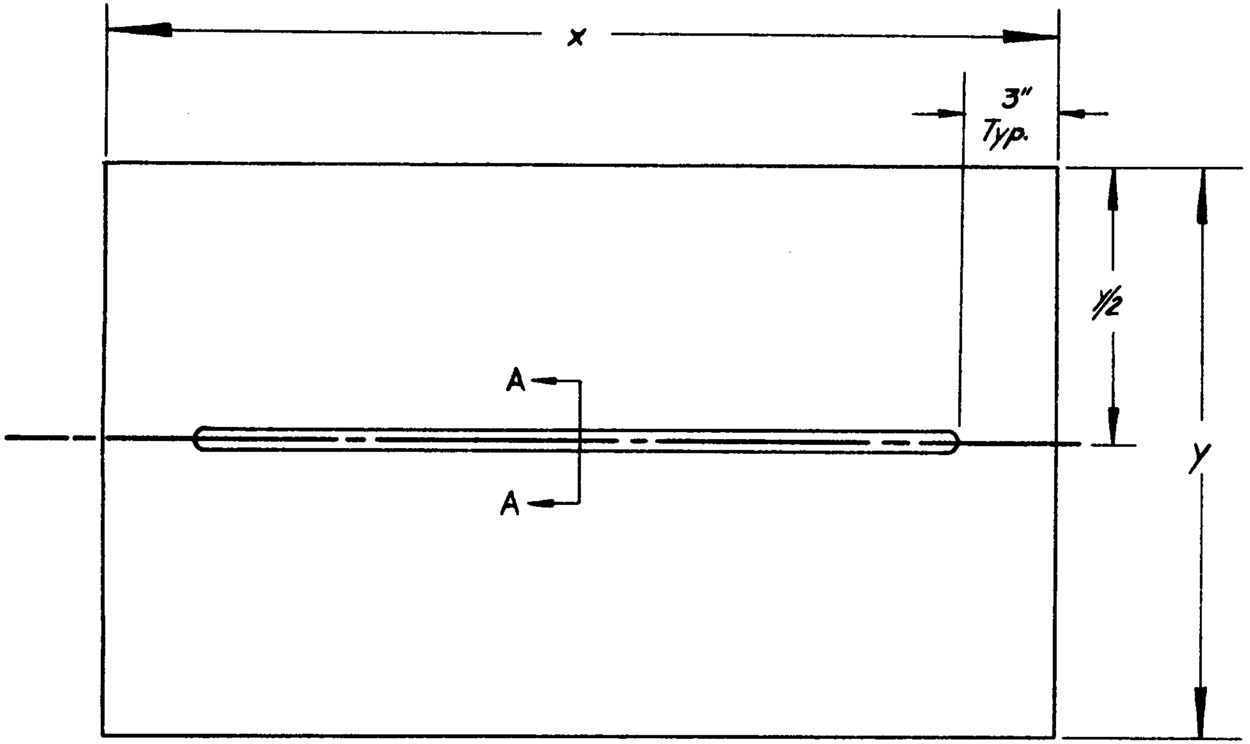
(b) 0.50-Inch and 1.00-Inch Plate Specimen

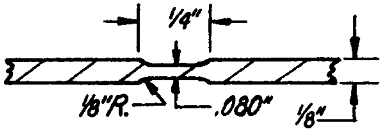
FIGURE E-1. TENSILE TEST SPECIMENS



Panel Sizes		
Dimension	1:1	2:1
x	36"	30"
y	36"	24"

FIGURE E-2. PARENT METAL BULGE TEST SPECIMENS

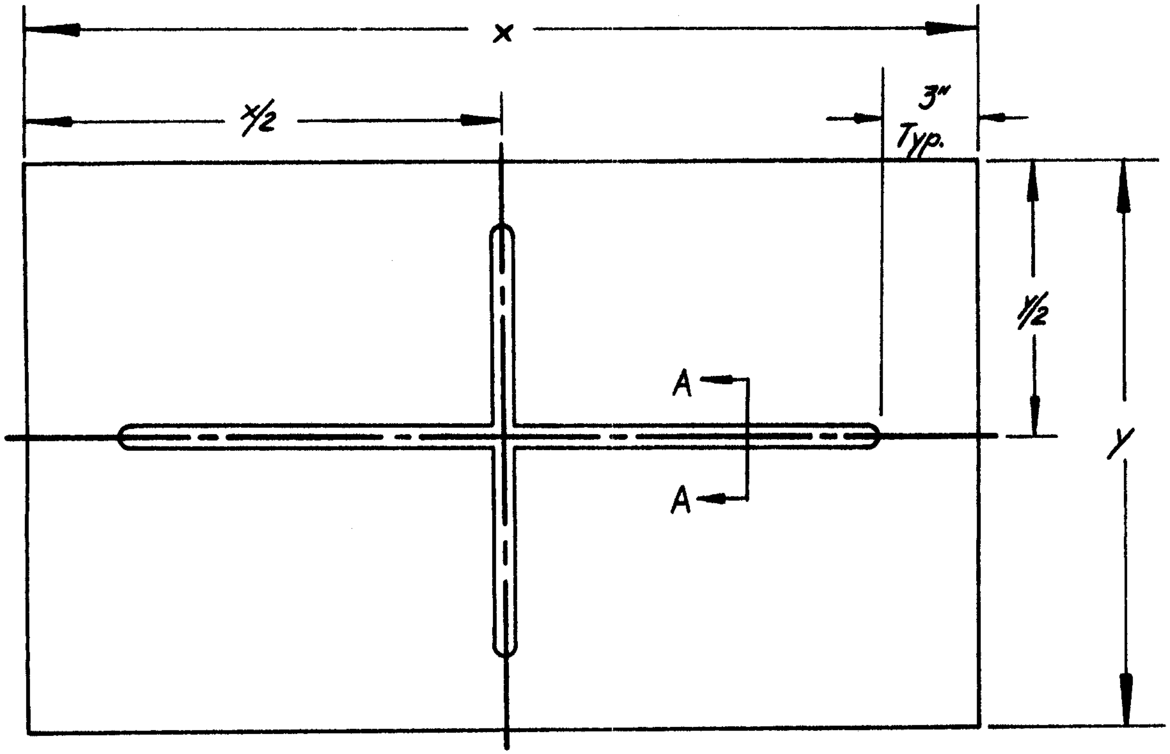


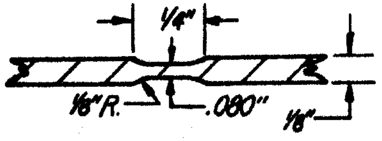


Groove Detail
Section A-A

Panel Sizes		
Dimension	1:1	2:1
X	30"	30"
Y	30"	24"

FIGURE E-3. SINGLE-GROOVE BULGE PANEL

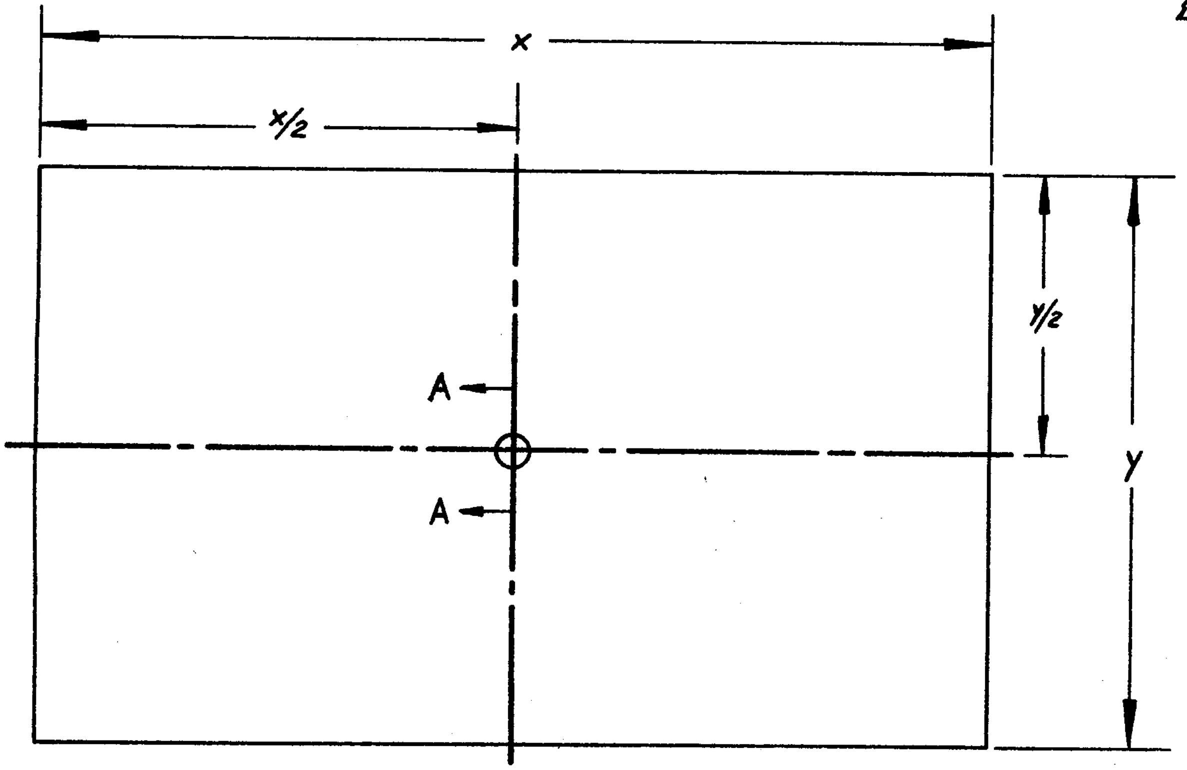


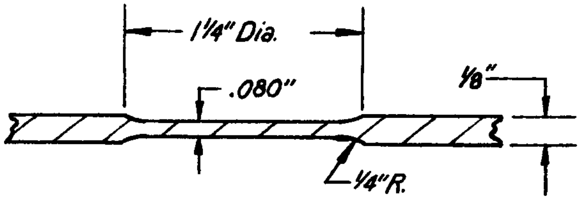


Groove Detail
Section A-A

Panel Sizes		
Dimension	1:1	2:1
X	30"	30"
Y	30"	24"

FIGURE E-4. CROSS-GROOVE BULGE PANEL

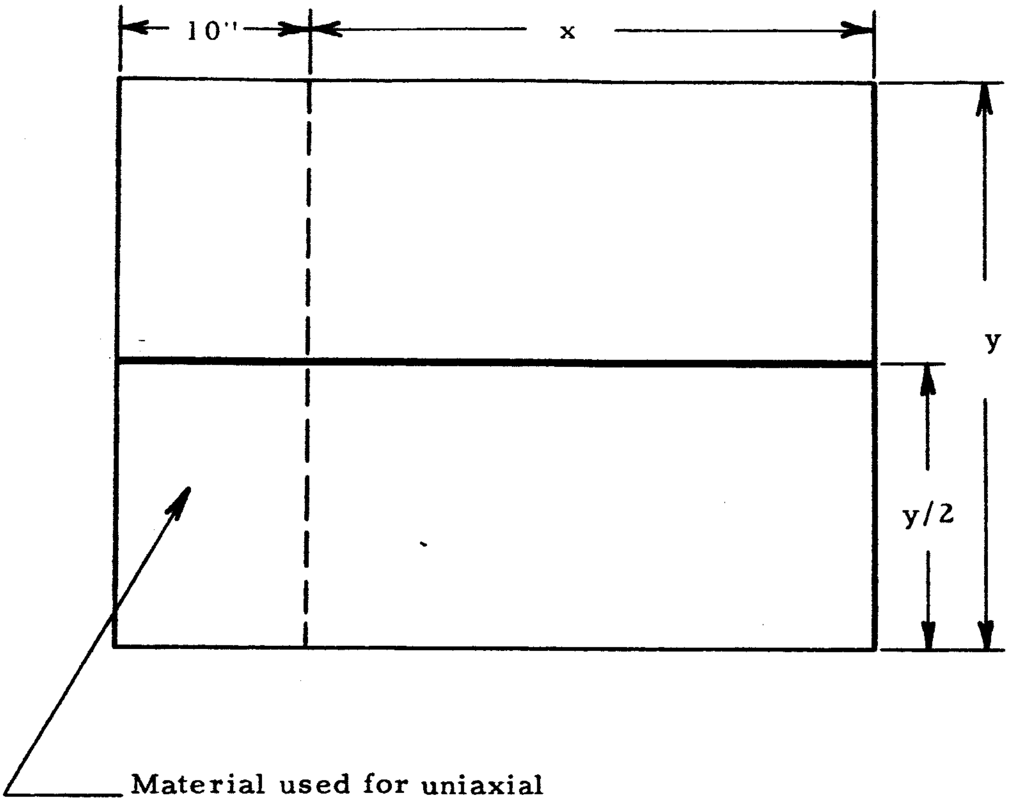




Detail of Reduced Section A-A

Panel Sizes		
Dimension	1:1	2:1
X	30"	30"
Y	30"	24"

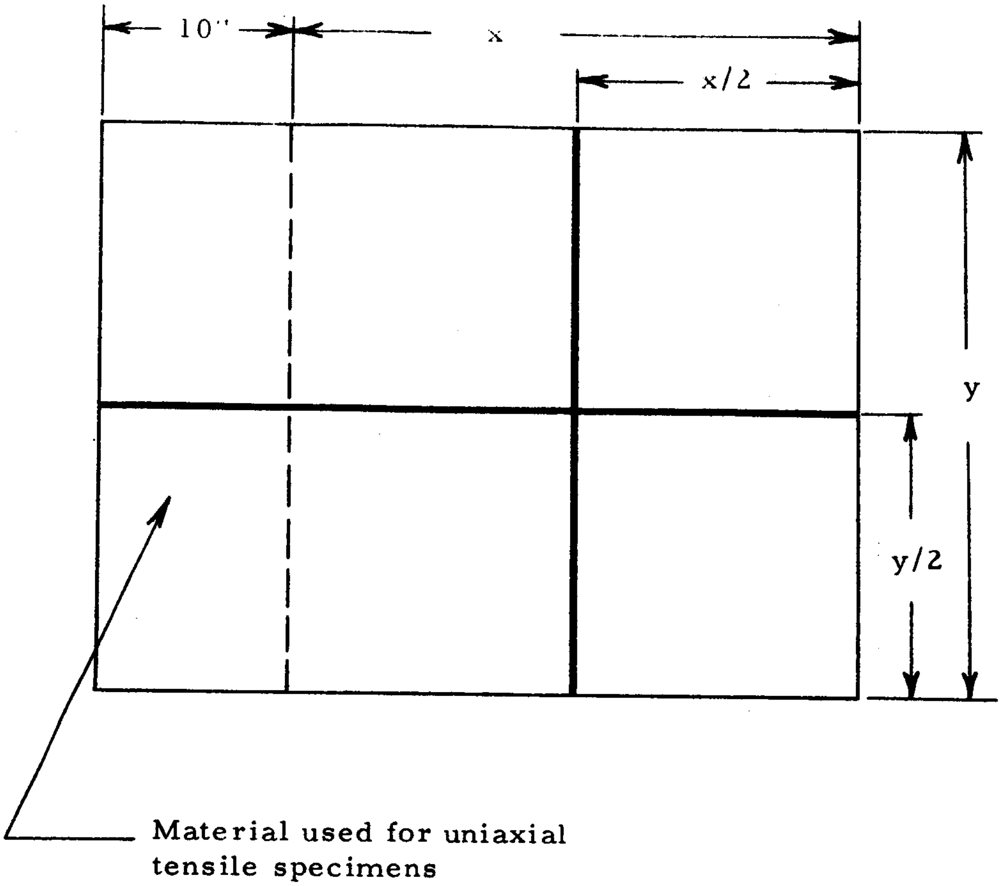
FIGURE E-5. REDUCED-SECTION BULGE PANEL



Material used for uniaxial tensile specimen

Panel Sizes		
Dimension	1:1	2:1
x	30"	30"
y	30"	24"

FIGURE E-6. SINGLE-WELD BULGE PANEL



Material used for uniaxial tensile specimens

Panel Sizes		
Dimension	1:1	2:1
x	30"	30"
y	30"	24"

FIGURE E-7. CROSS-WELD BULGE PANEL

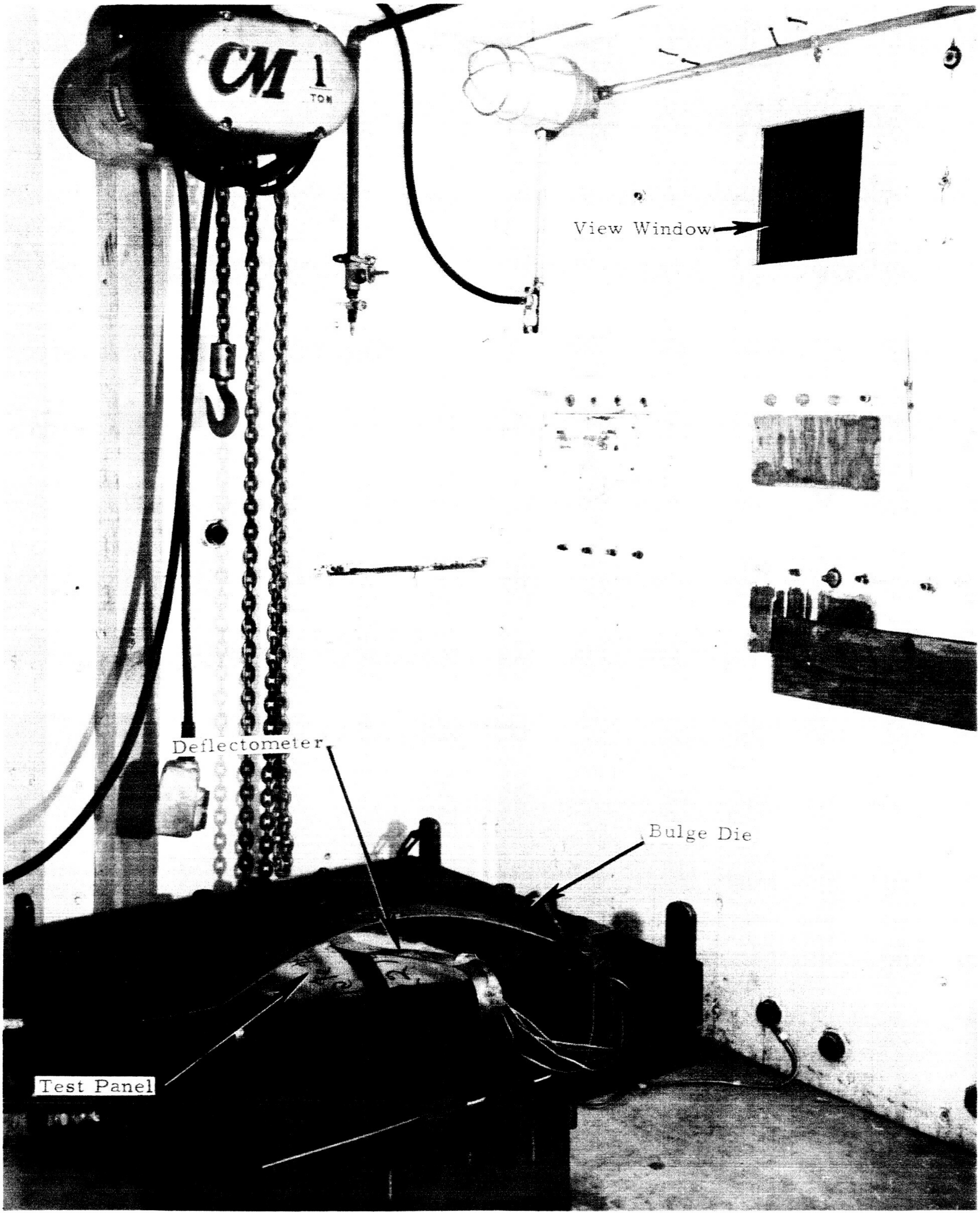


FIGURE E-8. CIRCULAR BULGE DIE AND TEST PANEL ASSEMBLY IN TEST CELL

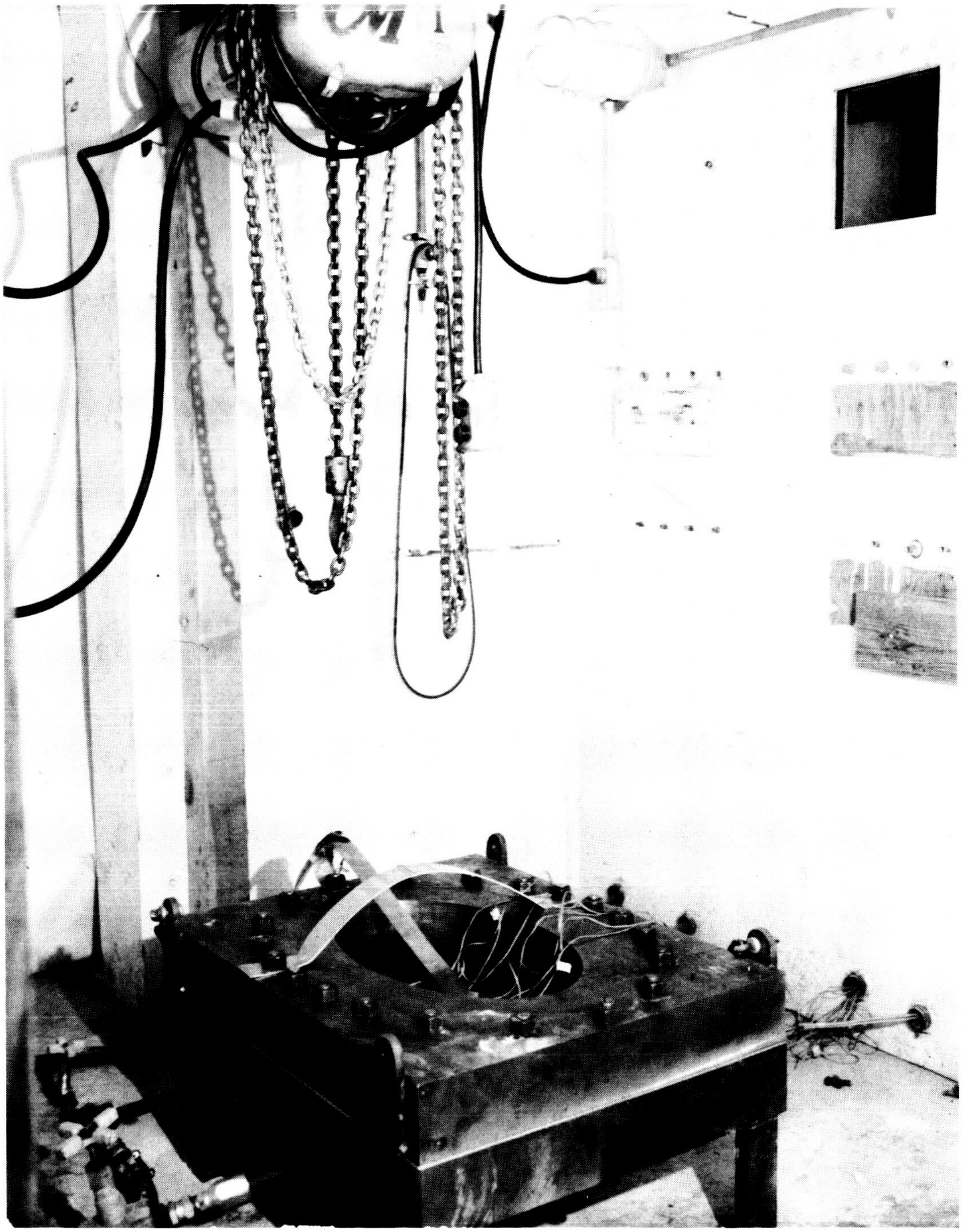


FIGURE E-9. ELLIPTICAL BULGE FIXTURE INSTALLED IN TEST CELL

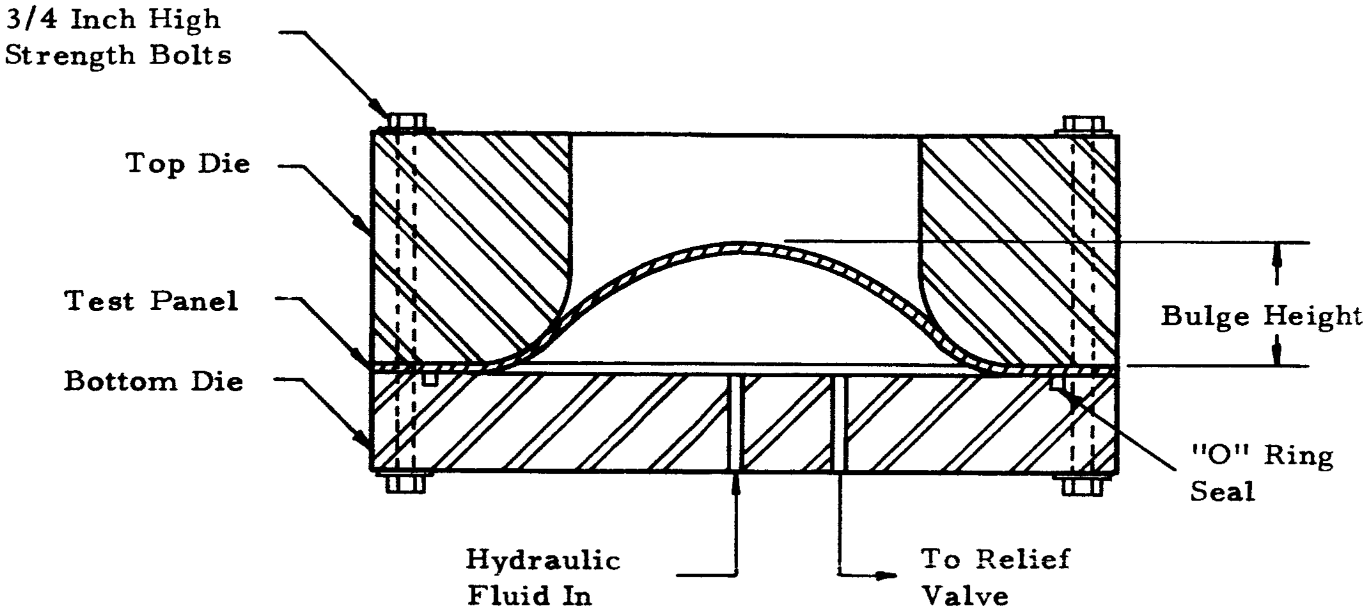


FIGURE E-10. SCHEMATIC DIAGRAM OF HYDRAULIC BULGE TEST FIXTURE

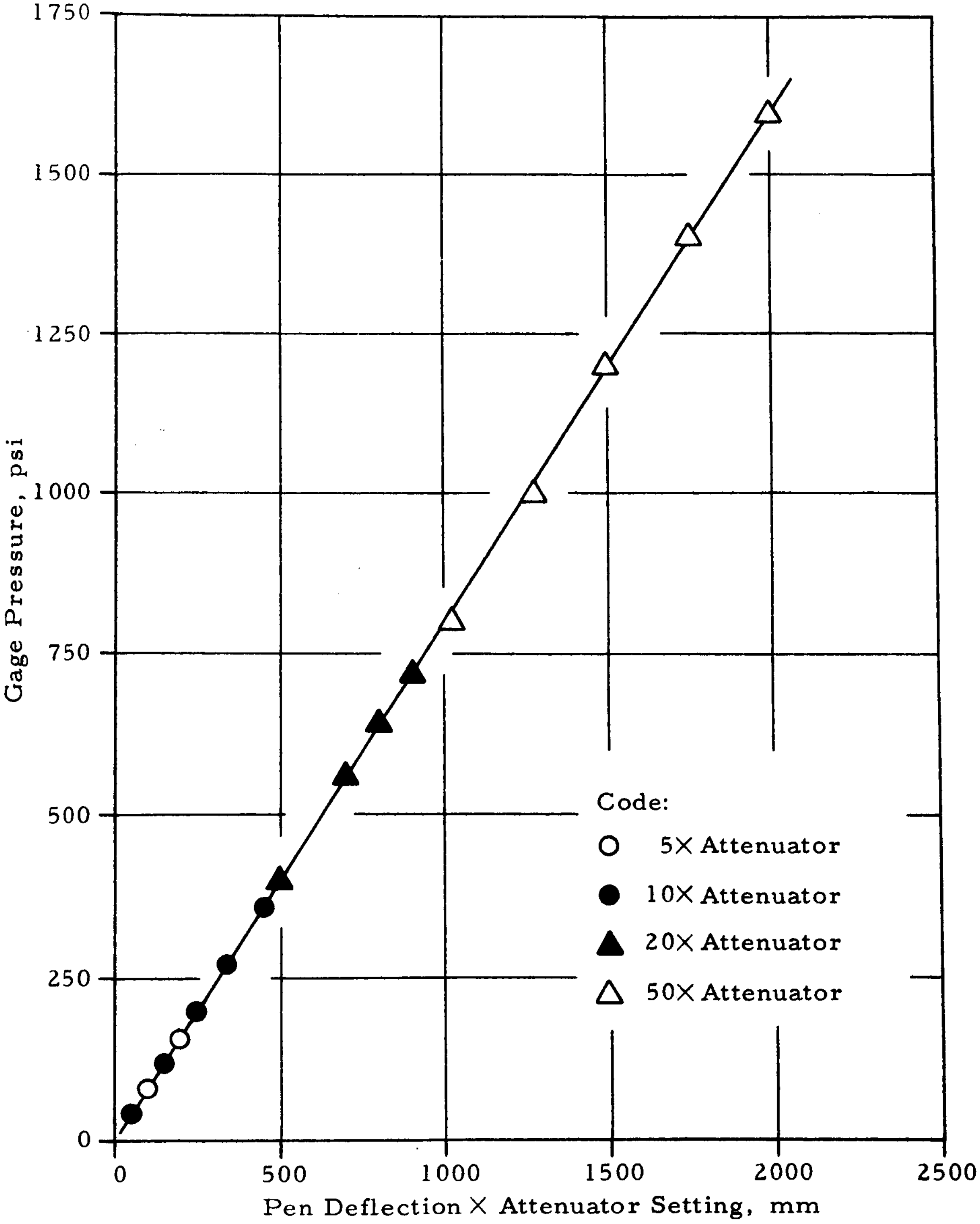


FIGURE E-11. CALIBRATION FOR PRESSURE TRANSDUCER INSTRUMENTATION

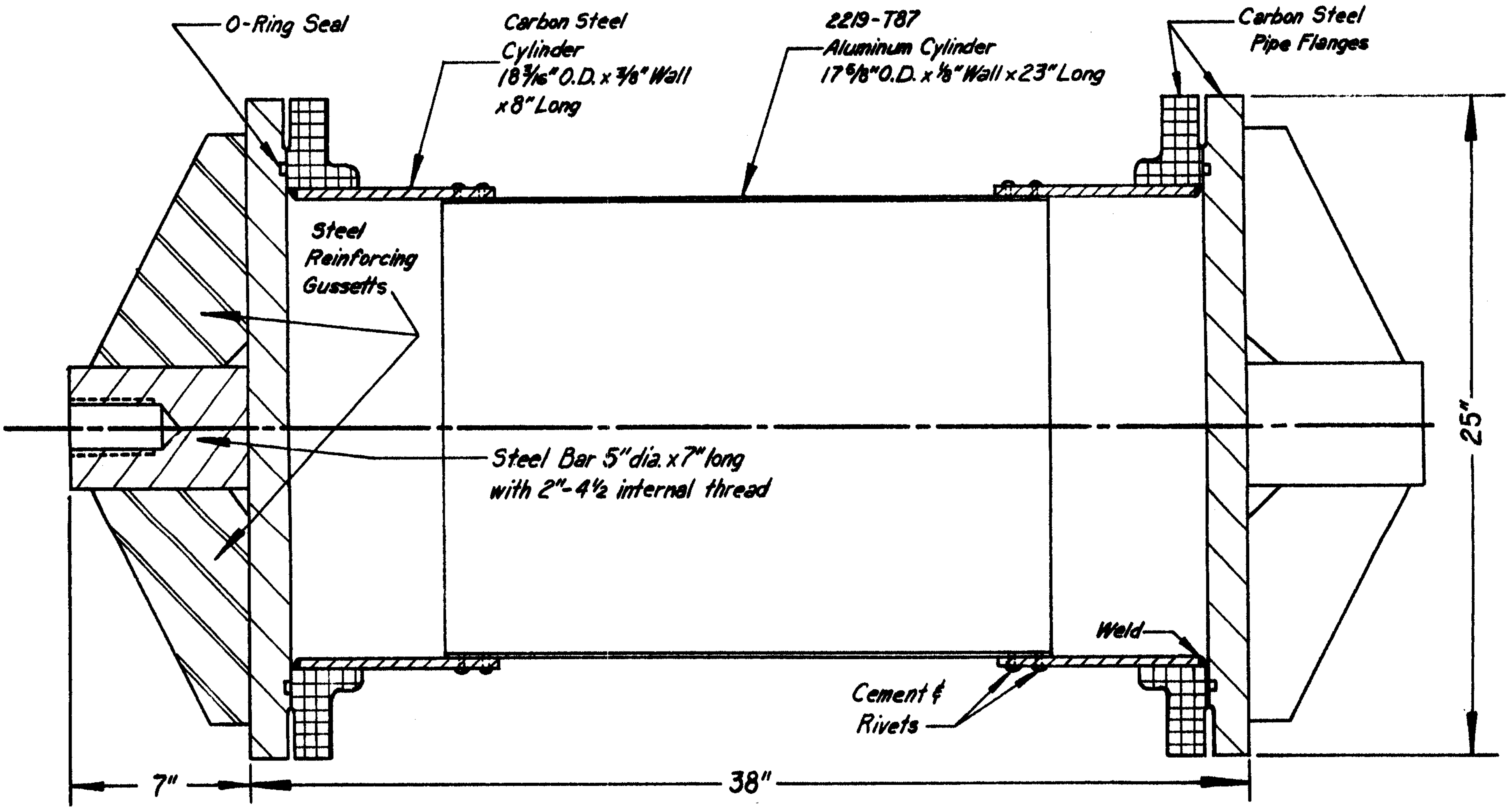


FIGURE E-12. REDESIGNED TEST CYLINDER AND CLOSURE FIXTURE ASSEMBLY

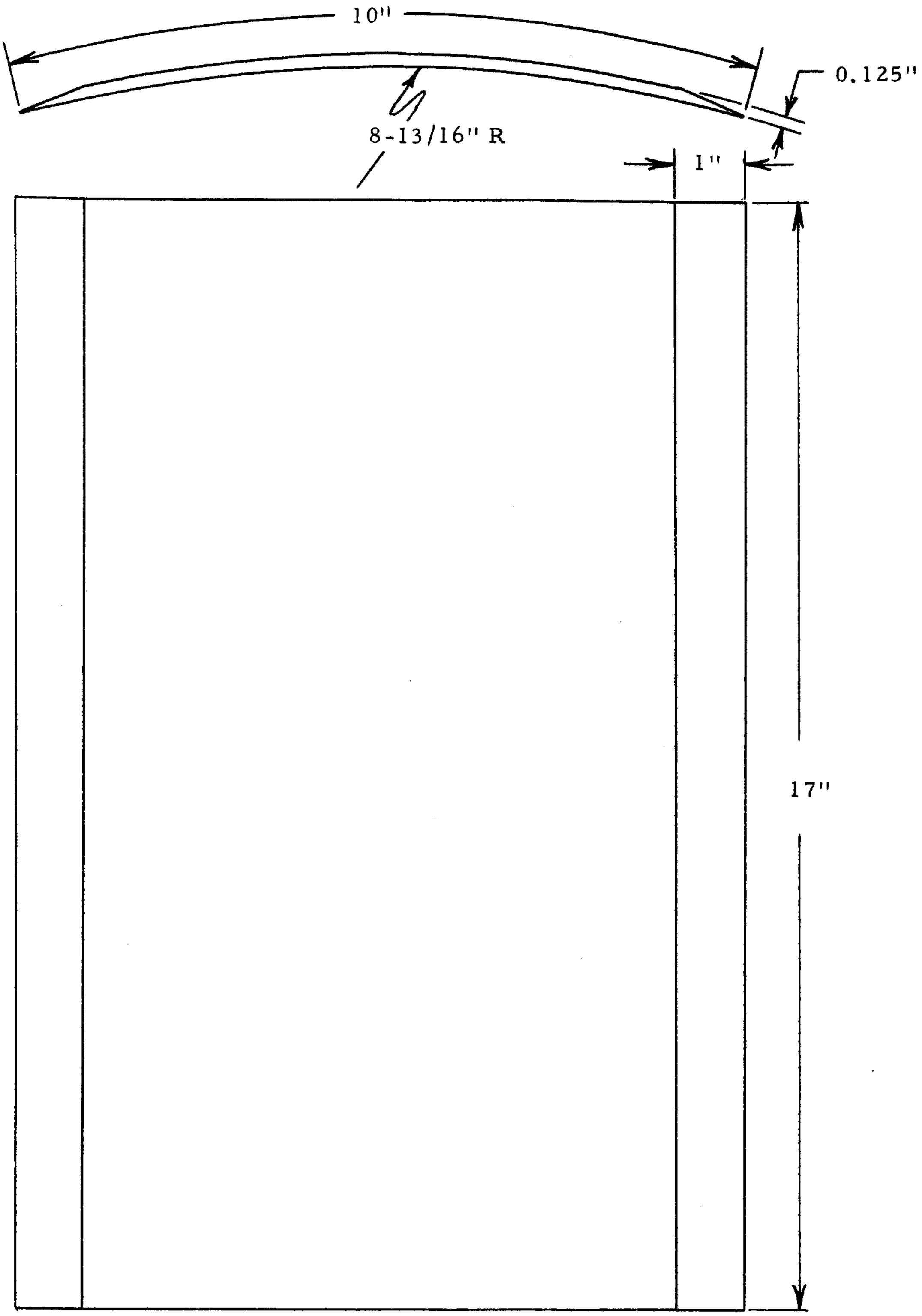
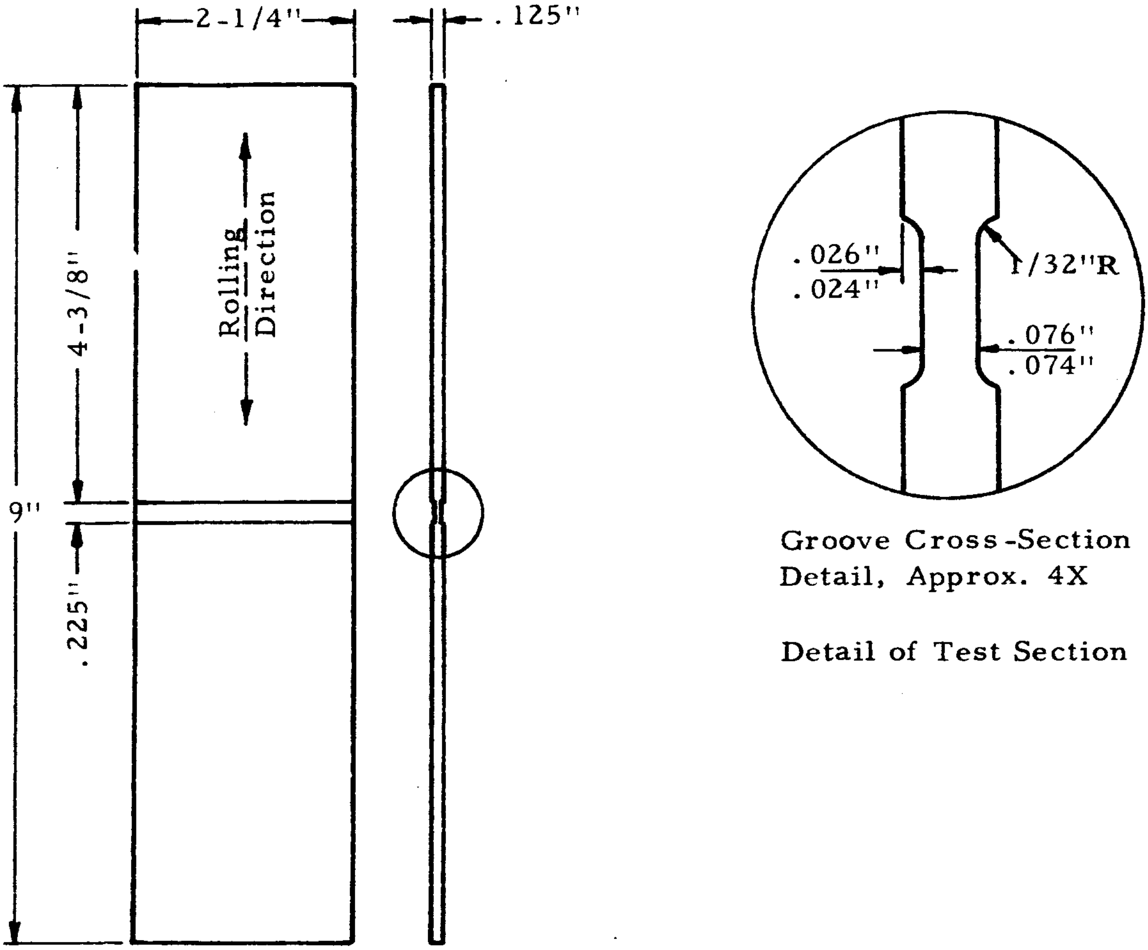


FIGURE E-13. CYLINDER REINFORCEMENT PLATE



Half Size

Groove Cross-Section Detail, Approx. 4X

Detail of Test Section

FIGURE E-14. MIT 2:1 BIAXIAL STRESS TEST SPECIMEN

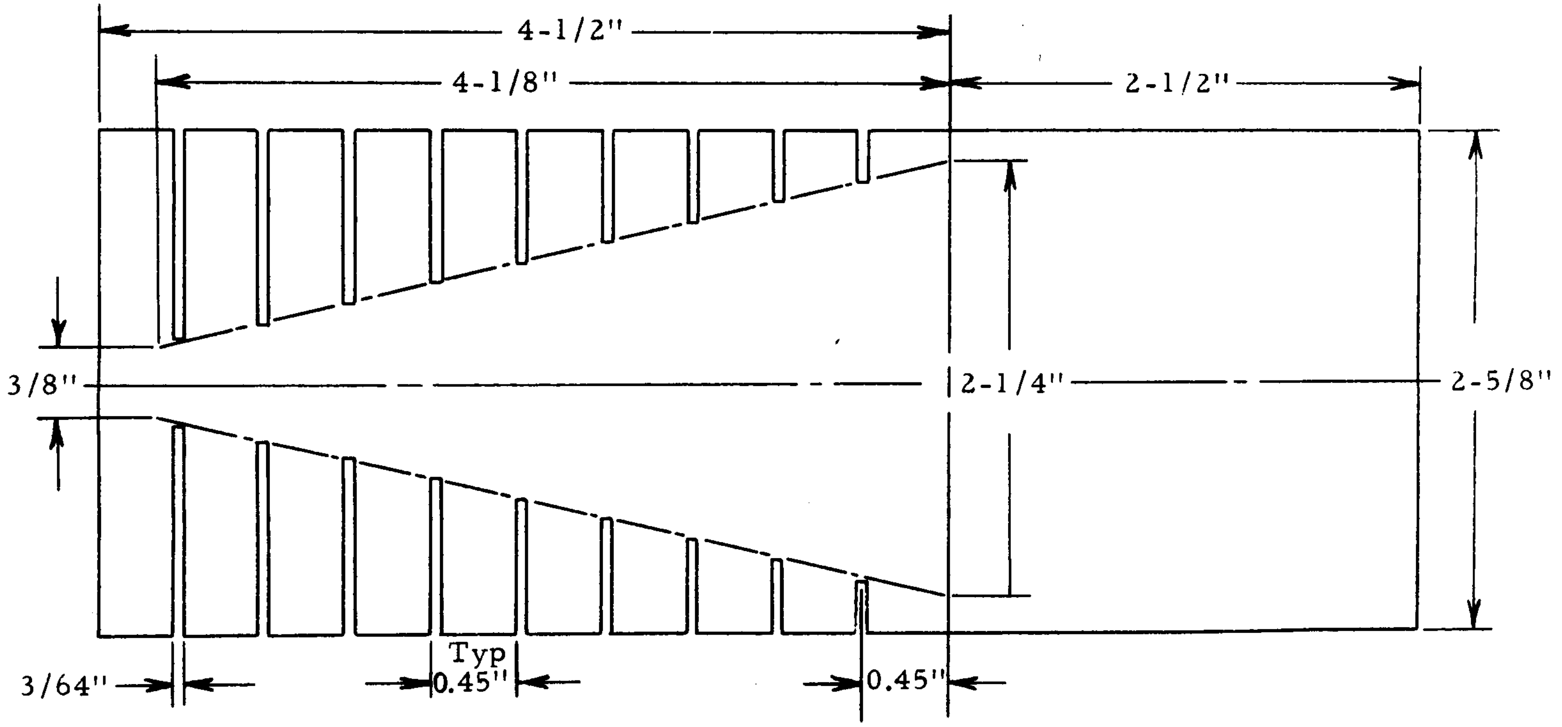


FIGURE E-15. MODIFIED HOULDCROFT CRACK SUSCEPTIBILITY TEST SPECIMEN (REF. 11)

TABLE E-1. WELDING PROCEDURES FOR HOULDCROFT CRACK SUSCEPTIBILITY TESTS

Current - 216 amps DCSP

Potential - 12 volts

Travel Speed - 14 ipm

Filler Wire Speed - 65 ipm

Electrode - 1/8" dia., 2% Thoriated Tungsten

Backup Block - 1" Thick Carbon

APPENDIX F

FABRICATION DATA (CONTRACT NAS8-20160)

FABRICATION DATA (CONTRACT NAS8-20160)

A. Welding Procedures

The Tungsten Inert Gas (TIG) welding was carried out utilizing a Miller 600-ampere AC-DC power supply, a Linde HWM-2 contour welding head equipped with a Linde cold wire feeder and a Linde HW13 TIG torch. The Metallic Arc Inert Gas (MIG) welding was carried out using a Linde SVI 500 constant potential power source along with a Linde SEH-2 welding head and a HW13 MIG torch. Both the TIG and MIG welding heads were mounted on a Linde OM-48 side beam carriage. The carriage and wire feed motors were controlled electronically using Linde electronic governors. In most cases, the amperage and voltage were continuously recorded on Leeds and Northrup, Speedomax H, strip chart recorders.

Prior to fabrication, all material was saw cut from the original plates. All weld joint preparation was accomplished by milling. The use of any lubricants and/or coolants was prohibited during the cutting and milling processes. Immediately prior to welding, the weld joint and adjacent plate material was solvent cleaned and hand draw filed.

The 0.125-inch and 0.187-inch thick panel blanks were fit and clamped in position using an Airline pneumatic positioner. A grooved, water-cooled, copper backup bar was used during the fabrication of these panels. Helium gas, directed through holes in the groove of the backup bar, was used to protect the root side of the weld.

The 0.50-inch and 1.00-inch thick panels were fabricated without the use of either backup bar or inert gas shielding of the root.

The welding procedures employed in the fabrication of all test panels are listed in Table F-1. The joint configurations used, along with typical cross sections of the completed welds, are shown in Figures F-1 through F-8.

Upon completion of each test panel, the height and width of the weld crowns were measured at several locations. These measurements are recorded in Tables F-2 through F-5.

B. Radiographic Inspection Procedures

Each welded aluminum panel was prepared for X-ray inspection by placing 1/4-inch lead numbers 6 inches apart along the length of the weldment.

In the case of a panel containing a cross weld, the second weld was indicated by the symbol W2 in lead letters. Other information placed on the welded panel with lead numbers included the date, exposure settings, panel thickness, and panel code number. This information was so located on the panels as to appear on each 17-inch length of film. ASME aluminum penetrameters as well as DIN 54 wire penetrameters were placed on each panel at the extreme ends of the weldment on the source side of the panel and shim stock corresponding in thickness to the weld buildup was positioned under each penetrameter.

All radiographs were made with a Baltospot 200 kv, 5 ma portable X-ray unit. Kodak Type M, 70 mm Redi-Pac strip film was used in all cases. The exposures employed for each weldment thickness were as follows:

Material Thickness, in.	Weld Thickness, in.	Penetrameters	Shim Thickness, in.	Source of Film Distance, in.	Potential, volts	Current, ma	Exposure Time, min
0.125	0.200	DIN 54 ASME #5, unshimmed ASME #5, shimmed	1/16	48	80	5.0	3
0.187	0.290	DIN 54 ASME #5, unshimmed ASME #5, shimmed	1/8	48	100	5.0	2
0.500	0.575	DIN 54 ASME 0.50, shimmed ASME 0.37, unshimmed	1/8	48	110	4.5	4.5
1.000	1.125	DIN 54 ASME 1.0, shimmed ASME 0.5, unshimmed	1/8	48	135	4.5	4.75

After the film was exposed, it was processed in a 68°F constant temperature developing tank according to the following procedure:

(1) Immersed and agitated intermittently in a 68°F developing solution (Kodak X-Ray Developer) for 6 minutes.

(2) Immersed and agitated continuously in a 68°F development stopping solution (200-1 mixture of water and acetic acid) for one minute.

(3) Immersed and agitated intermittently in a 68°F fixing solution (Kodak X-Ray Fixer) for 10 minutes.

(4) Immersed in flowing water at 68°F and allowed to wash for a minimum of 30 minutes.

(5) Immersed in a wetting agent (Kodak Photo-Flo), squeegeed off and hung to dry.

After drying, the film was placed on a radiographic film viewer containing a variable intensity light source and analyzed thoroughly. All apparent defects were noted and recorded on a form which indicated type of defect, location and magnitude.

The acceptance of a weldment from the radiographic inspection standpoint was based on the following conditions:

(1) No cracking was evident in the weldment

(2) No lack of fusion was evident in the weldment

(3) No slag greater than 1/8 T was evident in the weldment

(4) No connected porosity with length greater than 1/8 T was evident in the weldment

(5) No single porosity locations with diameters greater than 1/8 T were evident in the weldment.

Localized regions of unacceptable porosity were noted in some of the weldments. These weldments were accepted for further testing if the regions of porosity were located so as not to influence the test results. Bulge panels containing such defects were accepted if the defects were located outside of the test section. In cases where localized porosity occurred in the X7106-T63 tensile test panels, the defect regions were cut from the panel and the remaining portion of the panel was used for tensile specimens.

C. Heat Treatment

The hydraulic bulge test program included a series of tests on parent metal panels and weldments in the annealed condition and the stress-relieved condition. These panels were heat-treated in a gas-fired muffle furnace. During the treatment, the panels were clamped between steel plates to minimize warping. The heat-treating operations were carried out at KO Steel Castings Company, San Antonio, Texas.

The specific treatments employed were as follows:

Annealing Treatment
2 hours at 775°F ± 25°F
Furnace cool to 300°F
Air cool to room temperature
Stress-Relieving Treatment
5 hours at 525°F ± 25°F
Air cool to room temperature

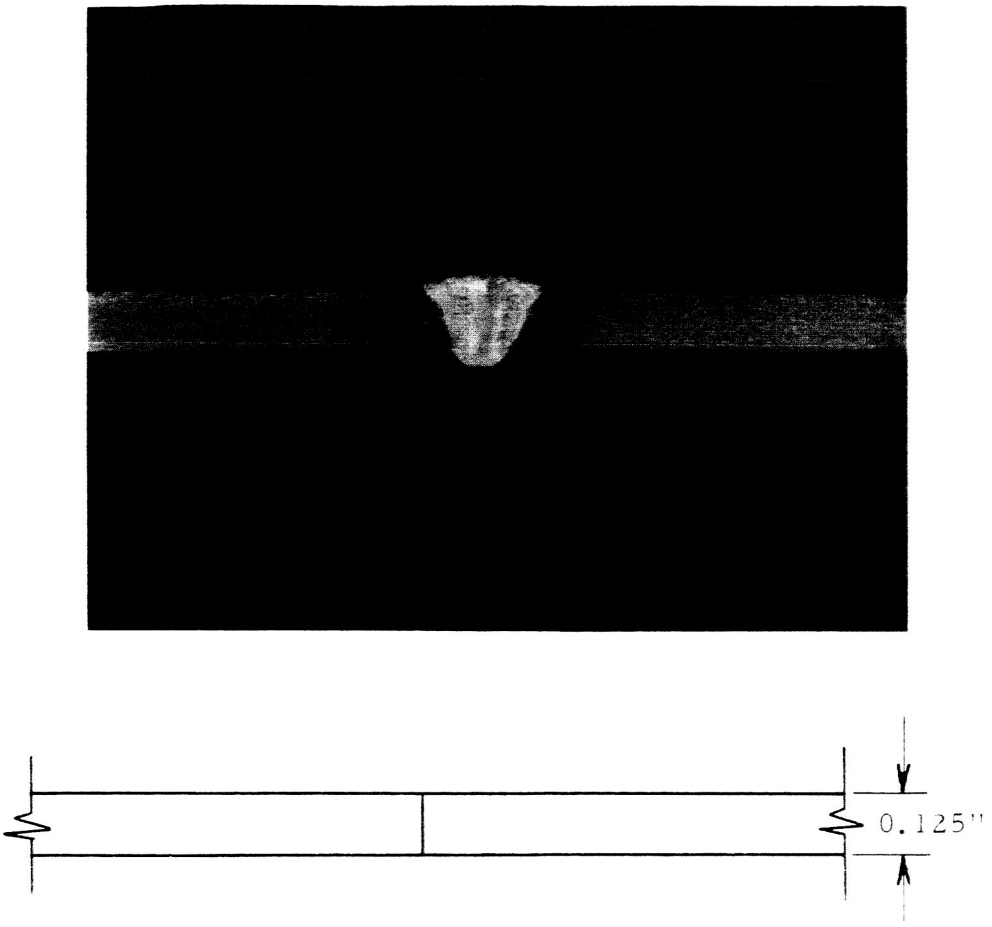
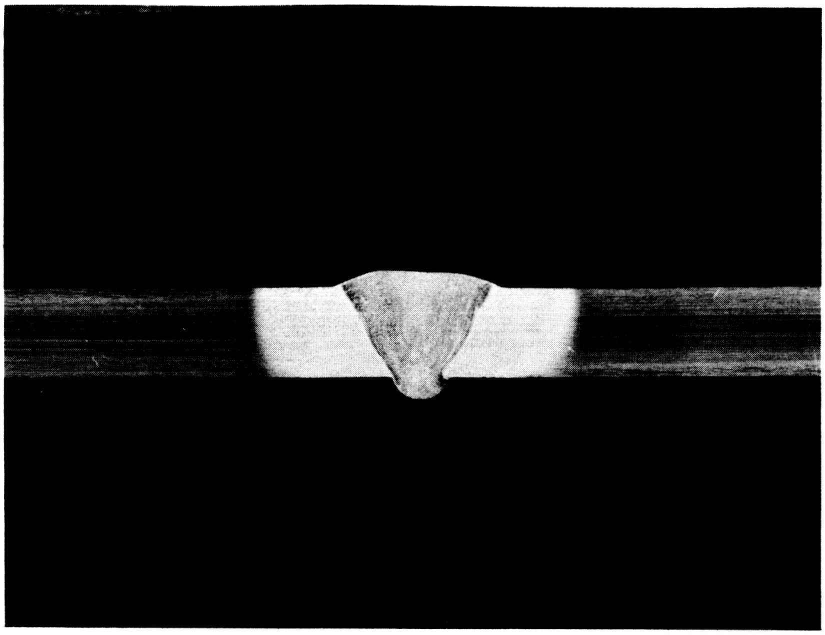


FIGURE F-1. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 0.125-INCH TIG WELDMENTS



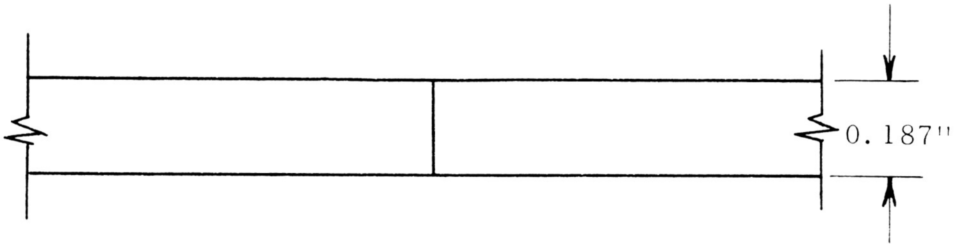


FIGURE F-2. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 0.187-INCH TIG WELDMENTS

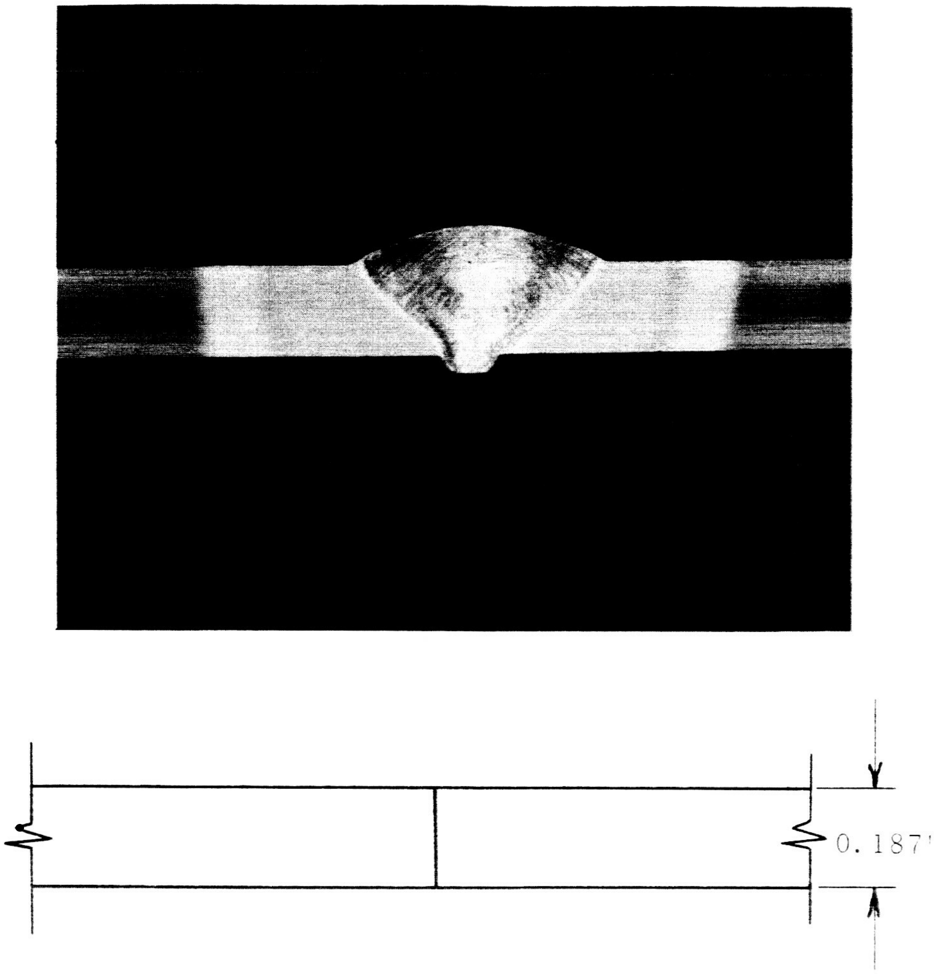


FIGURE F-3. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 0.187-INCH MIG WELDMENTS

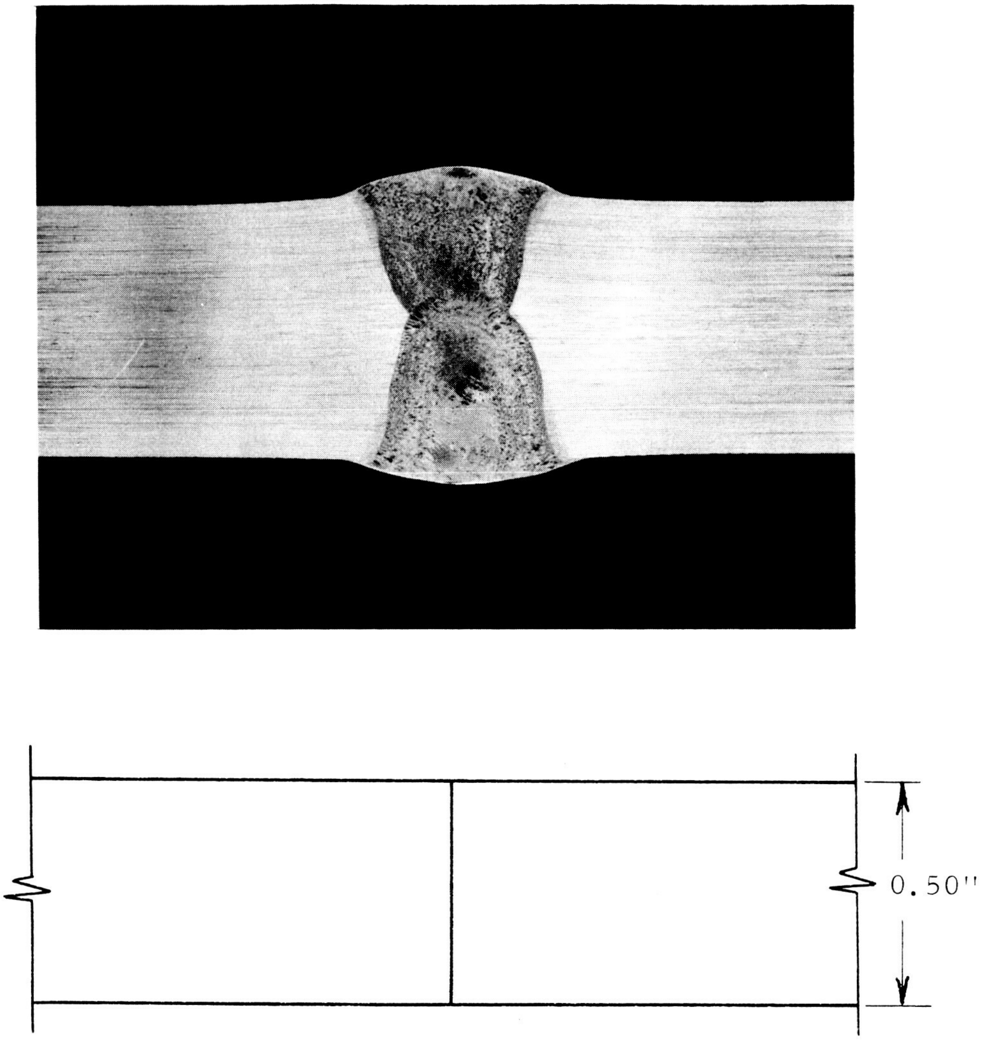


FIGURE F-4. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 0.50-INCH TIG SQUARE BUTT WELDMENTS

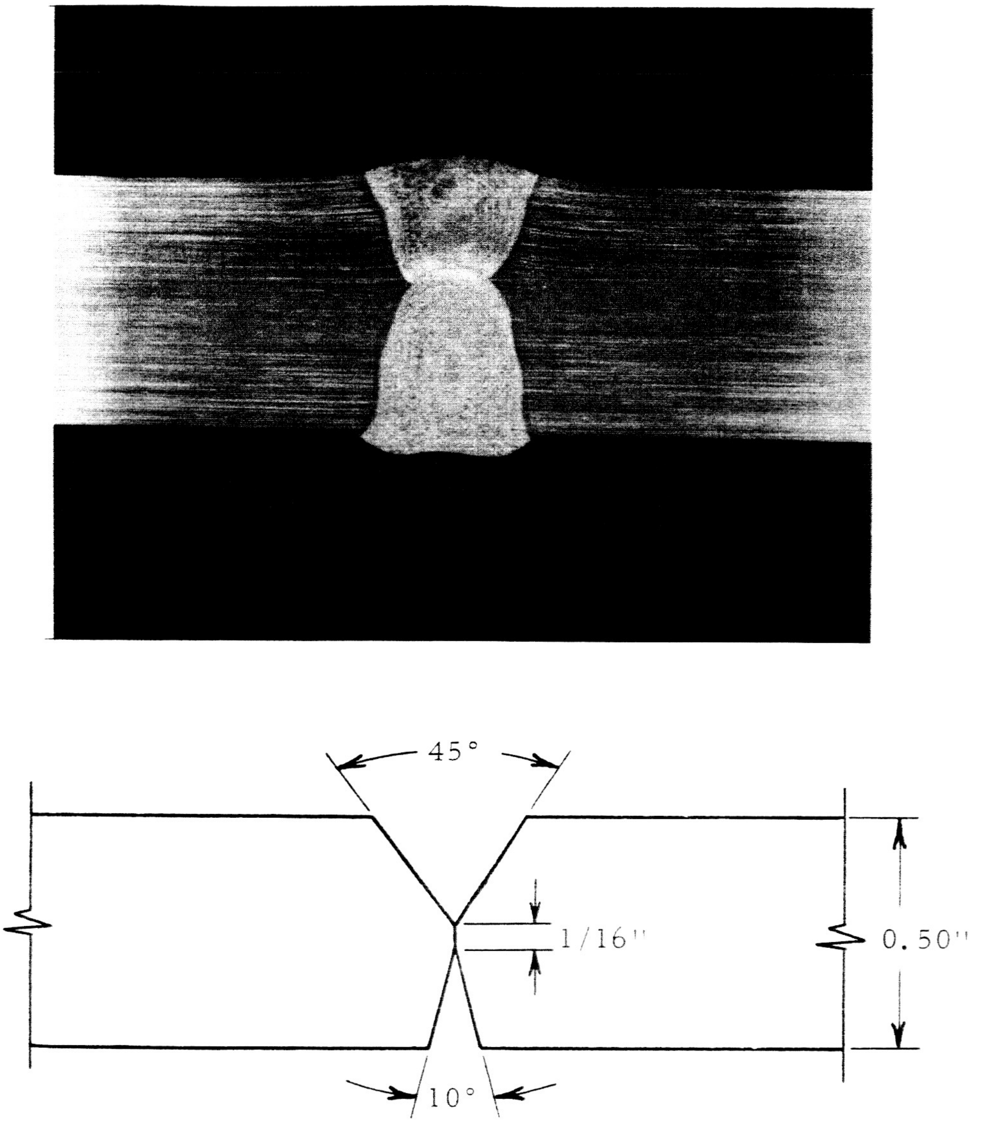


FIGURE F-5. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 0.50-INCH TIG DOUBLE V WELDMENTS

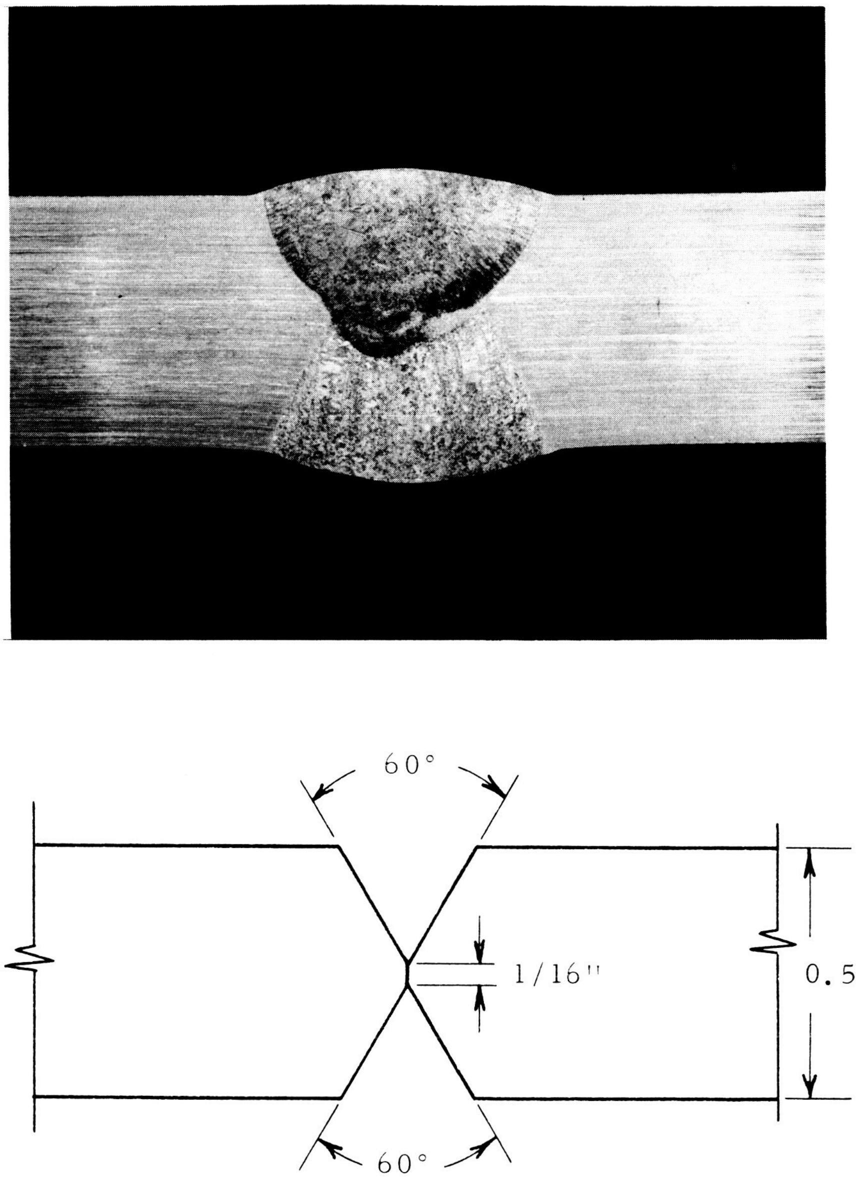
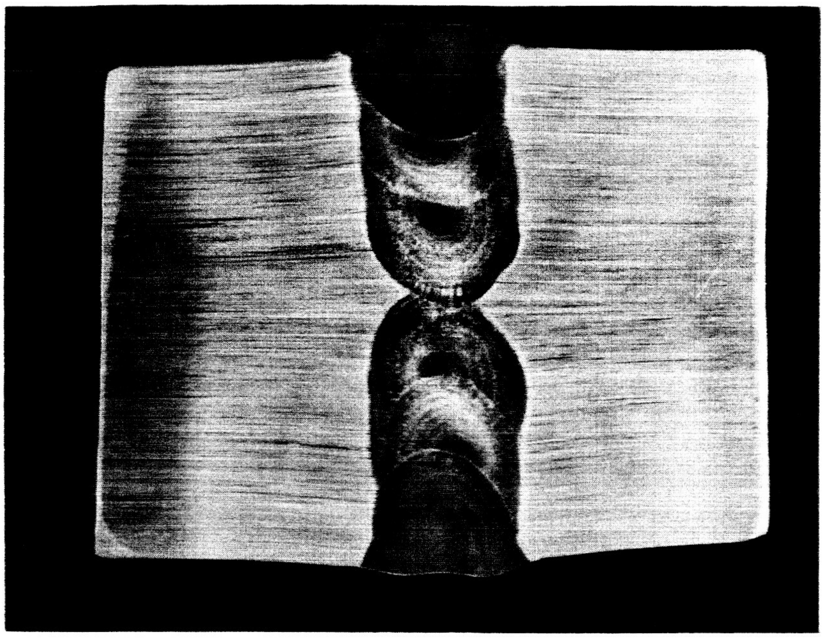


FIGURE F-6. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 0.50-INCH MIG WELDMENTS



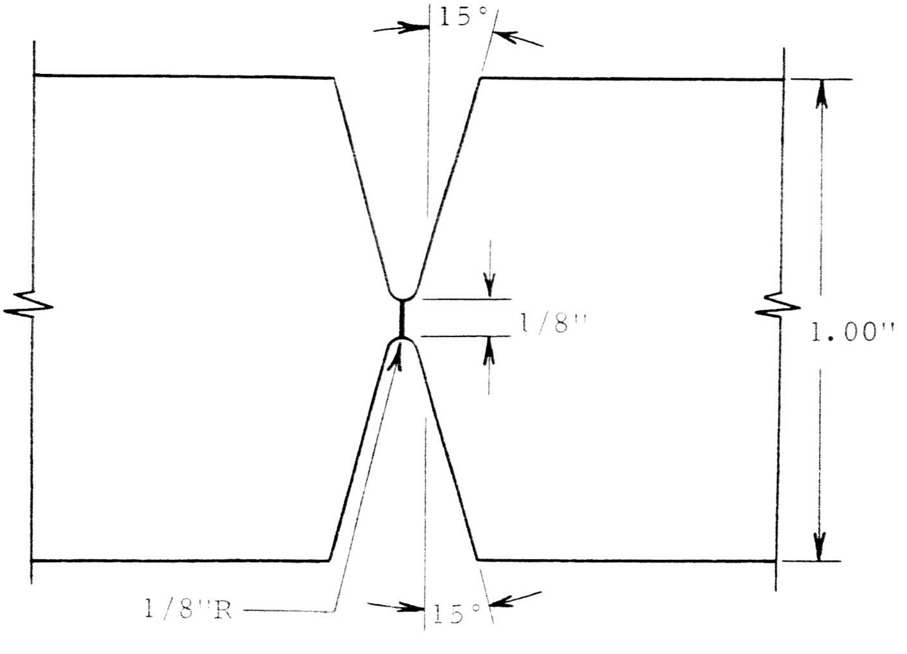


FIGURE F-7. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 1.00-INCH TIG WELDMENTS

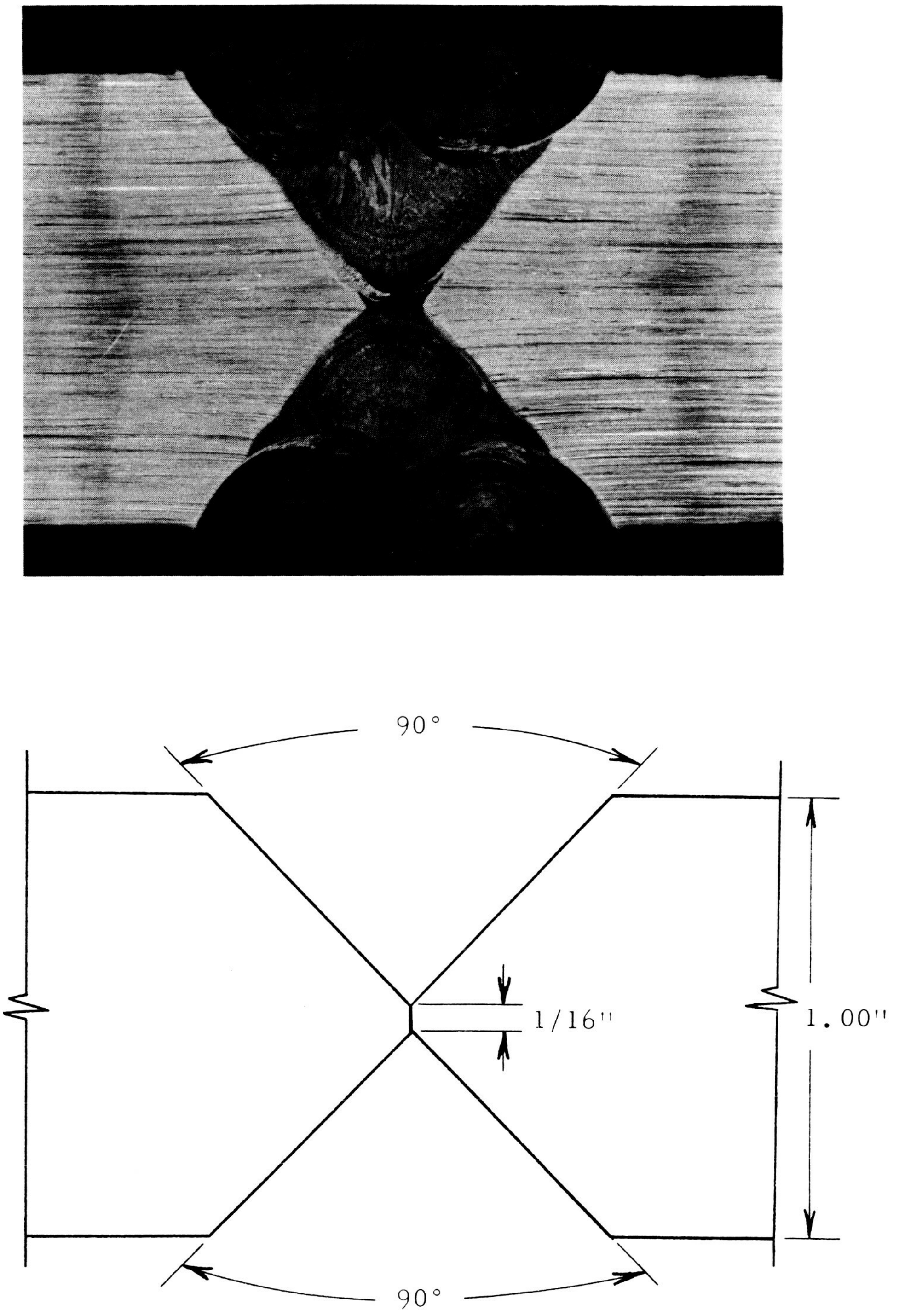


FIGURE F-8. TYPICAL CROSS-SECTION AND JOINT PREPARATION FOR 1.00-INCH MIG WELDMENTS

TABLE F-1. WELDING PROCEDURES

Welding Procedure	Alloy/Joint Design	Material Thickness (inches)	Welding Process	Filler Metal/ Size (inches)	No. of Passes	Electrode Composition/Size (inches)	Current (amps)	Voltage (volts)	Shield Gas/ Flow (cfh)	Back-up Gas/ Flow (cfh)	Travel Speed (ipm)	Filler Metal Speed (ipm)
65A-1	2219-T87/ Sq Butt	0.125	TIG	2319/ 3/64	1	Tungsten 2% Thoria/ 1/8	200 DCSP	11	He/30	He/5	15	64
65A-2	7106-T63/ Sq Butt	0.187	TIG	X5180/ 3/64	1	Tungsten 2% Thoria/ 1/8	280 DCSP	11	He/30	He/5	14	85
65A-3	7106-T63/ Sq Butt	0.187	TIG	5356/ 3/64	1	Tungsten 2% Thoria/ 1/8	280 DCSP	11	He/30	He/5	14	85
65A-4	7106-T63/ Sq Butt	0.187	TIG	5556/ 3/64	1	Tungsten 2% Thoria/ 1/8	280 DCSP	11	He/30	He/5	14	85
65A-5	7106-T63/ Sq Butt	0.187	MIG	X5180 3/64	1	X5180 3/64	250 DCRP	31	He/50 A+O_2/5	-	33	-
65A-6	7106-T63/ Sq Butt	0.187	MIG	5356/ 3/64	1	5356/ 3/64	250 DCRP	31	He/50 A+O_2/5	-	33	-
65A-7	7106-T63/ Sq Butt	0.187	MIG	5556/ 3/64	1	5556/ 3/64	250 DCRP	31	He/50 A+O_2/5	-	33	-
65A-8	7106-T63/ Double V	0.50	MIG	X5180/ 3/64	2	X5180/ 3/64	300 DCRP	34	He/50 A+O_2/5	-	33	-
65A-9	7106-T63/ Double V	0.50	MIG	5356/ 3/64	2	5356/ 3/64	300 DCRP	34	He/50 A+O_2/5	-	33	-
65A-10	7106-T63/ Double V	0.50	MIG	5556/ 3/64	2	5556/ 3/64	300 DCRP	34	He/50 A+O_2/5	-	33	-
65A-11	7106-T63/ Sq Butt	0.50	TIG	X5180/ 3/64	2	Tungsten 2% Thoria/ 1/8	316 DCSP	12	He/35	-	7	56
65A-12	7106-T63/ Sq Butt	0.50	TIG	5356/ 3/64	2	Tungsten 2% Thoria/ 1/8	316 DCSP	12	He/35	-	7	56
65A-13	7106-T63/ Sq Butt	0.50	TIG	5556/ 3/64	2	Tungsten 2% Thoria/ 1/8	316 DCSP	12	He/35	-	7	56
65A-14	7106-T63/ Double V	0.50	TIG	X5180/ 3/64	1 of 2	Tungsten 2% Thoria/ 1/8	312 DCSP	12	He/35	-	10	52
					2 of 2	Tungsten 2% Thoria/ 1/8	300 DCSP	12	He/35	-	8	122
65A-15	7106-T63/ Double V	0.50	TIG	5356/ 3/64	1 of 2	Tungsten 2% Thoria/ 1/8	312 DCSP	12	He/35	-	10	52
					2 of 2	Tungsten 2% Thoria/ 1/8	300 DCSP	12	He/35	-	8	122
65A-16	7106-T63/ Double V	0.50	TIG	5556/ 3/64	1 of 2	Tungsten 2% Thoria/ 1/8	312 DCSP	12	He/35	-	10	52
					2 of 2	Tungsten 2% Thoria/ 1/8	300 DCSP	12	He/35	-	8	122
65A-17	7106-T63/ Double V	1.0	TIG	X5180/ 1/16	1 of 8	Tungsten 2% Thoria/ 5/32	265 DCSP	12	He/35	-	7	42
					2 of 8	Tungsten 2% Thoria/ 5/32	276 DCSP	12	He/35	-	7	42
					3 of 8	Tungsten 2% Thoria/ 5/32	344 DCSP	12	He/35	-	4	42

TABLE F-1. WELDING PROCEDURES (Cont'd)

Welding Procedure	Alloy/Joint Design	Material Thickness (inches)	Welding Process	Filler Metal/ Size (inches)	No. of Passes	Electrode Composition/Size (inches)	Current (amps)	Voltage (volts)	Shield Gas/ Flow (cfh)	Back-up Gas Flow (cfh)	Travel Speed (ipm)	Filler Metal Speed (ipm)
65A-17	7106-T63 Double V	1.0	TIG	5180/ 1/16	4 of 8	Tungsten 2% Thoria/ 5/32	344 DCSP	12	He/35	-	4	42
					5 of 8	Tungsten 2% Thoria/ 5/32	320 DCSP	12	He/35	-	5	42
					6 of 8	Tungsten 2% Thoria/ 5/32	320 DCSP	12	He/35	-	5	42
					7 of 8	Tungsten 2% Thoria/ 5/32	260 DCSP	12	He/35	-	5	52
					8 of 8	Tungsten 2% Thoria/ 5/32	260 DCSP	12	He/35	-	5	52
65A-18	7106-T63 Double V	1.0	TIG	5356/ 1/16	1 of 8	Tungsten 2% Thoria/ 5/32	265 DCSP	12	He/35	-	7	42
					2 of 8	Tungsten 2% Thoria/ 5/32	276 DCSP	12	He/35	-	7	42
					3 of 8	Tungsten 2% Thoria/ 5/32	344 DCSP	12	He/35	-	4	42
					4 of 8	Tungsten 2% Thoria/ 5/32	344 DCSP	12	He/35	-	4	42
					5 of 8	Tungsten 2% Thoria/ 5/32	320 DCSP	12	He/35	-	5	42
					6 of 8	Tungsten 2% Thoria/ 5/32	320 DCSP	12	He/35	-	5	42
					7 of 8	Tungsten 2% Thoria/ 5/32	260 DCSP	12	He/35	-	5	52
					8 of 8	Tungsten 2% Thoria/ 5/32	260 DCSP	12	He/35	-	5	52
65A-19	7106-T63 Double V	1.0	TIG	5556/ 1/16	1 of 8	Tungsten 2% Thoria/ 5/32	265 DCSP	12	He/35	-	7	42
					2 of 8	Tungsten 2% Thoria/ 5/32	276 DCSP	12	He/35	-	7	42
					3 of 8	Tungsten 2% Thoria/ 5/32	344 DCSP	12	He/35	-	4	42
					4 of 8	Tungsten 2% Thoria/ 5/32	344 DCSP	12	He/35	-	4	42
					5 of 8	Tungsten 2% Thoria/ 5/32	320 DCSP	12	He/35	-	5	42
					6 of 8	Tungsten 2% Thoria/ 5/32	320 DCSP	12	He/35	-	5	42
					7 of 8	Tungsten 2% Thoria/ 5/32	260 DCSP	12	He/35	-	5	52

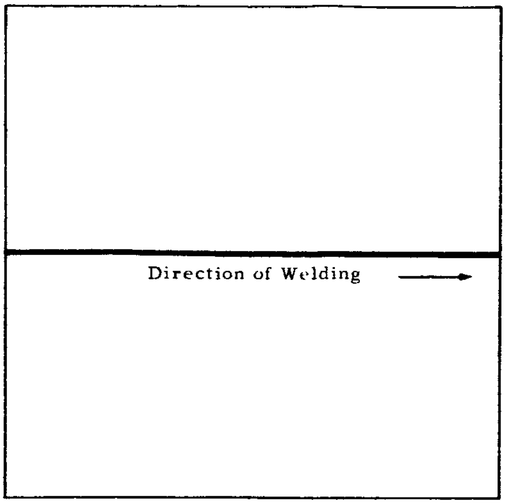
TABLE F-1. WELDING PROCEDURES (Cont'd)

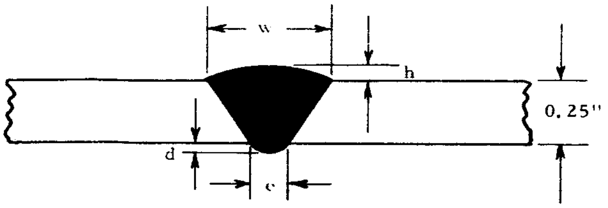
Welding Procedure	Alloy/Joint Design	Material Thickness (inches)	Welding Process	Filler Metal/ Size (inches)	No. of Passes	Electrode Composition/Size (inches)	Current (amps)	Voltage (volts)	Shield Gas/ Flow (cfh)	Back-up Gas/ Flow (cfh)	Travel Speed (ipm)	Filler Metal Speed (ipm)
65A-19	7106-T63/ Double V	1.0	TIG	5556/ 1/16	8 of 8	Tungsten 2% Thoria/ 5/32	260 DCSP	12	He/35	-	5	52
65A-20	7106-T63/ Double V	1.0	MIG	X5180/ 1/16	1 of 8	X5180/ 1/16	280 DCRP	36	He/50 A+O_2/5	-	26	-
					2 of 8	X5180/ 1/16	290 DCRP	34	He/50 A+O_2/5	-	26	-
					3 of 8	X5180/ 1/16	320 DCRP	34	He/50 A+O_2/5	-	11	-
					4 of 8	X5180/ 1/16	320 DCRP	34	He/50 A+O_2/5	-	11	-
					5 of 8	X5180/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					6 of 8	X5180/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					7 of 8	X5180/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					8 of 8	X5180/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
65A-21	7106-T63/ Double V	1.0	MIG	5336/ 1/16	1 of 8	5356/ 1/16	280 DCRP	36	He/50 A+O_2/5	-	26	-
					2 of 8	5356/ 1/16	290 DCRP	34	He/50 A+O_2/5	-	26	-
					3 of 8	5356/ 1/16	320 DCRP	34	He/50 A+O_2/5	-	11	-
					4 of 8	5356/ 1/16	320 DCRP	34	He/50 A+O_2/5	-	11	-
					5 of 8	5356/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					6 of 8	5356/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					7 of 8	5356/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					8 of 8	5356/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
65A-22	7106-T63/ Double V	1.0	MIG	5556/ 1/16	1 of 8	5556/ 1/16	280 DCRP	36	He/50 A+O_2/5	-	26	-
					2 of 8	5556/ 1/16	290 DCRP	34	He/50 A+O_2/5	-	26	-
					3 of 8	5556/ 1/16	320 DCRP	34	He/50 A+O_2/5	-	11	-
					4 of 8	5556/ 1/16	320 DCRP	34	He/50 A+O_2/5	-	11	-
					5 of 8	5556/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					6 of 8	5556/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					7 of 8	5556/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
					8 of 8	5556/ 1/16	300 DCRP	34	He/50 A+O_2/5	-	26	-
65A-23	7106-T63/ Sq Butt	0.125	TIG	X5180/ 3/64	1	Tungsten 2% Thoria/ 3/32	200 DCSP	11	He/30	He/5	15	64

TABLE F-1. WELDING PROCEDURES (Cont'd)

Welding Procedure	Alloy/Joint Design	Thickness (inches)	Welding Process	Size (inches)	No. of Passes	Electrode Composition/Size (inches)	Current (amps)	Voltage (volts)	Shield Gas/ Flow (cfh)	Back-up Gas Flow (cfh)	Travel Speed (ipm)	Filler Metal Speed (ipm)
65A-24	2014-T6/ Sq Butt	0.125	TIG	2319/ 3/64	1	Tungsten 2% Thoria/ 3/32	216 DCSP	12	He/30	He/5	15	64
65A-25	2014-T6/ Sq Butt	0.125	TIG	4043/ 3/64	1	Tungsten 2% Thoria/ 3/32	220 DCSP	12	He/30	He/5	15	64
65A-26	2219-T87/ Sq Butt	0.125	MIG	2319/ 3/64	1	2319/ 3/64	195 DCRP	32	He/40 A/25	He/5	43	-
65A-27	2014-T6/ Sq Butt	0.125	MIG	4043/ 3/64	1	4043/ 3/64	195 DCRP	32	He/40 A/25	He/5	43	-

TABLE F-2. WELD DIMENSIONS FOR SINGLE-WELD BULGE PANELS





A = distance from start of weld

Panel No.	A	w	h Inches	d	e
AT1-2	4	0.130	0.025	0.048	0.120
	8	0.122	0.024	0.048	0.120
	12	0.260	0.029	0.037	0.120
	16	0.220	0.022	0.053	0.120
	20	0.235	0.022	0.051	0.125
	24	0.228	0.025	0.048	0.125
	28	0.245	0.023	0.053	0.125
AT1-3	4	0.240	0.025	0.045	0.120
	8	0.286	0.020	0.049	0.120
	12	0.290	0.025	0.030	0.120
	16	0.265	0.025	0.039	0.130
	20	0.300	0.024	0.032	0.120
	24	0.285	0.026	0.034	0.120
	28	0.291	0.029	0.027	0.120
AT1-7	4	0.300	0.024	0.025	0.120
	8	0.293	0.019	0.042	0.118
	12	0.310	0.025	0.025	0.120
	16	0.300	0.025	0.026	0.120
	20	0.293	0.025	0.032	0.120
	24	0.300	0.027	0.026	0.120
	28	0.290	0.045	0.032	0.120
AT1-10	4	0.217	0.024	0.044	0.120
	8	0.240	0.032	0.036	0.120
	12	0.280	0.027	0.042	0.120
	16	0.285	0.026	0.027	0.120
	20	0.245	0.029	0.035	0.123
	24	0.292	0.029	0.043	0.122
	28	0.250	0.027	0.054	0.120
AT1-11	4	0.250	0.030	0.034	0.120
	8	0.250	0.031	0.036	0.120
	12	0.264	0.032	0.033	0.120
	16	0.286	0.027	0.023	0.120
	20	0.255	0.030	0.037	0.120
	24	0.235	0.027	0.047	0.120
	28	0.242	0.029	0.047	0.120
AT1-12	4	0.255	0.026	0.041	0.120
	8	0.245	0.029	0.040	0.120
	12	0.244	0.028	0.040	0.118
	16	0.235	0.029	0.046	0.119
	20	0.256	0.030	0.041	0.120
	24	0.245	0.026	0.050	0.118
	28	0.241	0.026	0.048	0.120
AT1-18	4	0.280	0.028	0.029	0.120
	8	0.285	0.023	0.036	0.121
	12	0.270	0.029	0.032	0.122
	16	0.279	0.022	0.045	0.122
	20	0.280	0.025	0.036	0.115
AT1-13 (cont'd)	24	0.285	0.020	0.046	0.118
	28	0.278	0.022	0.040	0.125
	32	0.285	0.024	0.039	0.115
	36	0.293	0.024	0.048	0.117
AT1-20	4	0.289	0.028	0.032	0.119
	8	0.239	0.024	0.038	0.125
	12	0.285	0.030	0.029	0.115
	16	0.293	0.026	0.035	0.119
	20	0.291	0.026	0.036	0.116
	24	0.300	0.024	0.037	0.119
	28	0.295	0.024	0.034	0.116
	32	0.285	0.024	0.039	0.116
	36	0.287	0.025	0.034	0.119
AM1-1	4	0.475	0.044	0.060	0.115
	8	0.468	0.052	0.052	0.110
	12	0.476	0.053	0.043	0.108
	16	0.460	0.056	0.055	0.118
	20	0.470	0.048	0.059	0.122
	24	0.474	0.046	0.058	0.118
	28	0.461	0.045	0.062	0.119
	32	0.482	0.040	0.060	0.118
	36	0.466	0.046	0.060	0.118
AM1-2	4	0.432	0.066	0.058	0.108
	8	0.442	0.055	0.047	0.103
	12	0.433	0.055	0.045	0.101
	16	0.459	0.054	0.045	0.091
	20	0.460	0.055	0.046	0.088
	24	0.465	0.056	0.047	0.104
	28	0.432	0.053	0.048	0.103
	32	0.468	0.050	0.062	0.120
	36	0.462	0.057	0.061	0.116
AM1-3	4	0.473	0.049	0.061	0.118
	8	0.458	0.054	0.062	0.116
	12	0.438	0.053	0.057	0.118
	16	0.448	0.050	0.053	0.119
	20	0.447	0.036	0.059	0.120
	24	0.438	0.034	0.059	0.116
	28	0.443	0.035	0.060	0.118
	32	0.446	0.043	0.062	0.117
	36	0.451	0.046	0.060	0.115
AM1-4	4	0.439	0.043	0.063	0.117
	8	0.441	0.045	0.061	0.119
	12	0.431	0.041	0.060	0.116
	16	0.444	0.049	0.050	0.107
	20	0.440	0.048	0.059	0.122
	24	0.436	0.050	0.060	0.118
	28	0.436	0.041	0.063	0.117

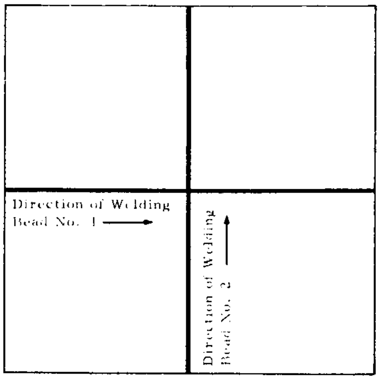
TABLE F-2. WELD DIMENSIONS FOR SINGLE-WELD BULGE PANELS (Cont'd)

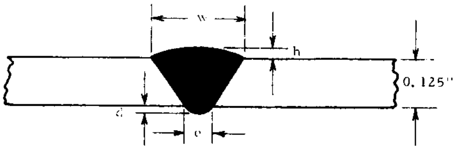
Panel No.	A	w	h	d	e
			Inches		
AM1-4 (cont'd)	32	0.445	0.053	0.061	0.116
	36	0.430	0.053	0.060	0.115
AM1-5	4	0.460	0.039	0.062	0.114
	8	0.466	0.045	0.062	0.116
	12	0.440	0.053	0.052	0.101
	16	0.463	0.051	0.050	0.100
	20	0.465	0.055	0.059	0.113
	24	0.448	0.051	0.059	0.113
	28	0.437	0.046	0.062	0.119
	32	0.456	0.048	0.060	0.117
	36	0.460	0.056	0.053	0.108
BT1-1	4	0.287	0.022	0.040	0.124
	8	0.286	0.024	0.039	0.125
	12	0.285	0.024	0.040	0.125
	16	0.281	0.025	0.038	0.126
	20	0.284	0.023	0.043	0.128
	24	0.291	0.025	0.045	0.123
	28	0.285	0.024	0.046	0.123
	32	0.302	0.026	0.029	0.134
	36	0.285	0.027	0.042	0.123
BT1-2	4	0.293	0.027	0.027	0.121
	8	0.293	0.026	0.027	0.123
	12	0.295	0.027	0.033	0.124
	16	0.297	0.029	0.024	0.124
	20	0.291	0.026	0.028	0.123
	24	0.298	0.031	0.026	0.103
	28	0.308	0.030	0.022	0.116
	32	0.308	0.030	0.021	0.104
	36	0.301	0.029	0.022	0.105
BT1-3	4	0.275	0.020	0.043	0.128
	8	0.284	0.028	0.036	0.135
	12	0.282	0.021	0.027	0.128
	16	0.294	0.027	0.031	0.132
	20	0.288	0.025	0.036	0.137
	24	0.286	0.026	0.047	0.125
	28	0.290	0.028	0.035	0.126
	32	0.320	0.029	0.023	0.130
	36	0.290	0.024	0.039	0.127
BT1-4	4	0.293	0.025	0.040	0.125
	8	0.292	0.026	0.036	0.127
	12	0.280	0.024	0.047	0.125
	16	0.290	0.025	0.035	0.124
	20	0.292	0.025	0.032	0.130
	24	0.292	0.028	0.038	0.126
	28	0.280	0.026	0.039	0.124
	32	0.305	0.029	0.027	0.135
	36	0.295	0.029	0.032	0.120
BT1-5	4	0.310	0.031	0.023	0.123
	8	0.307	0.028	0.023	0.127
	12	0.305	0.029	0.027	0.124
	16	0.314	0.030	0.023	0.123
	20	0.307	0.030	0.025	0.122
	24	0.313	0.030	0.022	0.106
	28	0.306	0.031	0.024	0.115
	32	0.315	0.034	0.020	0.097
	36	0.313	0.032	0.021	0.104
BT2-1	4	0.315	0.025	0.023	0.120
	8	0.317	0.027	0.023	0.122
	12	0.305	0.025	0.022	0.115
	16	0.320	0.029	0.022	0.120
	20	0.318	0.030	0.021	0.120
	24	0.320	0.031	0.020	0.115
	28	0.321	0.031	0.021	0.113
BT2-2	4	0.326	0.027	0.021	0.120
	8	0.318	0.032	0.023	0.122
	12	0.320	0.028	0.022	0.117
	16	0.320	0.029	0.023	0.122
	20	0.315	0.030	0.022	0.114
	24	0.310	0.030	0.021	0.106
BT2-2 (cont'd)	28	0.325	0.034	0.022	0.116
	32	0.320	0.031	0.023	0.115
	36	0.328	0.030	0.025	0.116
BT2-3	4	0.325	0.024	0.024	0.121
	8	0.322	0.030	0.024	0.124
	12	0.323	0.029	0.023	0.124
	16	0.320	0.026	0.025	0.123
	20	0.317	0.031	0.022	0.122
	24	0.311	0.031	0.020	0.116
	28	0.318	0.031	0.019	0.118
	32	0.320	0.030	0.024	0.119
	36	0.323	0.031	0.022	0.115
BT2-4	4	0.284	0.023	0.038	0.126
	8	0.286	0.026	0.039	0.126
	12	0.284	0.019	0.049	0.124
	16	0.286	0.024	0.040	0.126
	20	0.292	0.025	0.034	0.127
	24	0.285	0.027	0.036	0.121
	28	0.288	0.027	0.037	0.122
	32	0.303	0.025	0.027	0.135
	36	0.285	0.025	0.038	0.119
BT2-5	4	0.284	0.020	0.047	0.122
	8	0.286	0.024	0.040	0.125
	12	0.279	0.020	0.047	0.121
	16	0.286	0.024	0.040	0.128
	20	0.290	0.026	0.036	0.125
	24	0.287	0.028	0.031	0.110
	28	0.291	0.029	0.032	0.118
	32	0.315	0.030	0.028	0.126
	36	0.287	0.027	0.037	0.119
BM2-1	4	0.480	0.045	0.061	0.132
	8	0.468	0.045	0.063	0.125
	12	0.458	0.045	0.060	0.122
	16	0.469	0.043	0.053	0.121
	20	0.460	0.046	0.059	0.126
	24	0.472	0.043	0.058	0.122
	28	0.465	0.045	0.060	0.120
	32	0.485	0.044	0.060	0.134
	36	0.470	0.046	0.061	0.118
BM2-2	4	0.465	0.048	0.030	0.105
	8	0.464	0.046	0.053	0.122
	12	0.470	0.046	0.055	0.122
	16	0.475	0.047	0.053	0.128
	20	0.470	0.044	0.061	0.120
	24	0.465	0.045	0.057	0.119
	28	0.469	0.050	0.051	0.121
	32	0.475	0.041	0.060	0.130
	36	0.463	0.046	0.062	0.120
BM2-3	4	0.457	0.045	0.049	0.121
	8	0.447	0.045	0.060	0.123
	12	0.462	0.049	0.052	0.126
	16	0.458	0.048	0.061	0.118
	20	0.458	0.045	0.059	0.124
	24	0.454	0.045	0.055	0.115
	28	0.458	0.043	0.061	0.119
	32	0.464	0.048	0.060	0.128
	36	0.444	0.042	0.059	0.118
BM2-4	4	0.440	0.044	0.055	0.119
	8	0.450	0.058	0.064	0.117
	12	0.450	0.053	0.053	0.113
	16	0.454	0.053	0.055	0.109
	20	0.444	0.049	0.047	0.116
	24	0.465	0.045	0.058	0.114
	28	0.448	0.051	0.060	0.120
	32	0.463	0.048	0.060	0.126
	36	0.451	0.051	0.058	0.111
BM2-5	4	0.455	0.047	0.056	0.124
	8	0.457	0.055	0.043	0.115
	12	0.453	0.048	0.052	0.115

TABLE F-2. WELD DIMENSIONS FOR SINGLE-WELD BULGE PANELS (Cont'd)

Panel No.	A	w	h	d	e
			Inches		
BM2-5	16	0.453	0.052	0.053	0.118
(cont'd)	20	0.457	0.044	0.059	0.120
	24	0.460	0.042	0.059	0.125
	28	0.456	0.040	0.056	0.118
	32	0.472	0.047	0.059	0.115
	36	0.460	0.043	0.061	0.118
CT3-5	4	0.271	0.044	0.024	0.088
	8	0.271	0.043	0.025	0.100
	12	0.270	0.044	0.023	0.095
	16	0.271	0.046	0.025	0.103
	20	0.274	0.039	0.027	0.113
	24	0.279	0.040	0.026	0.118
	28	0.280	0.045	0.027	0.083
	32	0.280	0.042	0.028	0.120
CT3-6	4	0.284	0.040	0.026	0.127
	8	0.252	0.032	0.029	0.120
	12	0.282	0.027	0.044	0.122
	16	0.286	0.035	0.029	0.120
	20	0.286	0.033	0.040	0.118
	24	0.270	0.036	0.022	0.116
	28	0.287	0.037	0.045	0.114
	32	0.270	0.032	0.021	0.104
CT3-7	4	0.285	0.030	0.028	0.123
CT3-7	8	0.283	0.029	0.026	0.121
(cont'd)	12	0.278	0.026	0.026	0.122
	16	0.283	0.031	0.020	0.121
	20	0.273	0.033	0.024	0.117
	24	0.289	0.021	0.024	0.121
	28	0.278	0.030	0.029	0.122
	32	0.276	0.029	0.034	0.123
CT3-8	4	0.296	0.034	0.024	0.107
	8	0.304	0.032	0.024	0.103
	12	0.299	0.035	0.025	0.103
	16	0.290	0.035	0.023	0.104
	20	0.304	0.033	0.022	0.105
	24	0.307	0.035	0.024	0.105
	28	0.309	0.032	0.027	0.106
	32	0.311	0.035	0.024	0.105
CT3-9	4	0.280	0.026	0.024	0.120
	8	0.269	0.025	0.028	0.118
	12	0.276	0.027	0.025	0.116
	16	0.275	0.027	0.023	0.116
	20	0.277	0.027	0.019	0.110
	24	0.278	0.024	0.021	0.119
	28	0.276	0.026	0.020	0.112
	32	0.277	0.027	0.023	0.109

TABLE F-3. WELD DIMENSIONS FOR CROSS-WELD BULGE PANELS

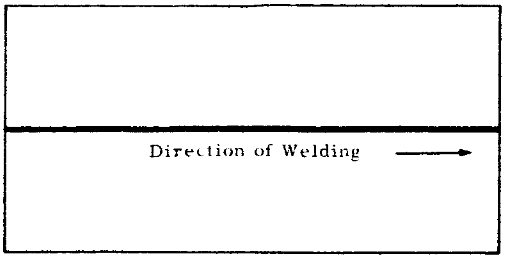


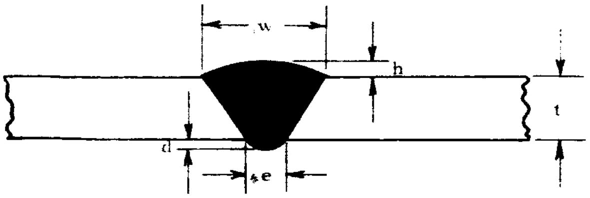


A - distance from start of weld No. 1
B distance from start of weld No. 2

Panel No.	A	Bead No. 1					Bead No. 2			
		w	h	d	e	B	w	h	d	e
		Inches					Inches			
AT1-1	4	0.250	0.024	0.044	0.121	4	0.275	0.023	0.052	0.140
	8	0.260	0.030	0.037	0.125	8	0.225	0.021	0.057	0.140
	12	0.240	0.023	0.046	0.125	12	0.240	0.024	0.057	0.132
	16	0.241	0.022	0.049	0.122	16	0.250	0.027	0.038	0.131
	20	0.250	0.026	0.044	0.124	20	0.247	0.027	0.047	0.127
	24	0.300	0.024	0.054	0.125	24	0.256	0.033	0.037	0.125
	28	0.267	0.037	0.038	0.125	28	0.255	0.037	0.038	0.125
AT1-4	4	0.246	0.022	0.042	0.125	4	0.282	0.016	0.051	0.135
	8	0.246	0.022	0.043	0.125	8	0.234	0.021	0.052	0.135
	12	0.250	0.026	0.047	0.125	12	0.225	0.027	0.061	0.132
	16	0.253	0.024	0.043	0.125	16	0.240	0.018	0.052	0.130
	20	0.282	0.030	0.032	0.125	20	0.247	0.025	0.044	0.130
	24	0.285	0.031	0.041	0.115					
	28	0.263	0.025	0.031	0.120					
AT1-5	4	0.240	0.024	0.046	0.122	4	0.245	0.020	0.056	0.135
	8	0.233	0.021	0.049	0.122	8	0.232	0.019	0.057	0.135
	12	0.250	0.028	0.041	0.120	12	0.245	0.021	0.055	0.135
	16	0.260	0.030	0.031	0.120	16	0.245	0.025	0.052	0.125
	20	0.242	0.026	0.042	0.125	20	0.272	0.029	0.044	0.125
	24	0.240	0.023	0.049	0.120					
	28	0.255	0.025	0.040	0.122					
AT1-6	4	0.245	0.028	0.025	0.119	4	0.225	0.021	0.048	0.135
	8	0.256	0.029	0.032	0.125	8	0.230	0.022	0.050	0.132
	12	0.235	0.023	0.045	0.123	12	0.223	0.033	0.050	0.125
	16	0.243	0.013	0.040	0.124	16	0.240	0.027	0.050	0.123
	20	0.231	0.011	0.050	0.123	20	0.241	0.029	0.049	0.125
	24	0.232	0.022	0.049	0.125					
	28	0.240	0.024	0.048	0.125					
AT1-8	4	0.250	0.023	0.033	0.123	4	0.238	0.021	0.044	0.135
	8	0.264	0.022	0.041	0.122	8	0.241	0.026	0.043	0.125
	12	0.250	0.033	0.038	0.123	12	0.236	0.026	0.044	0.125
	16	0.239	0.027	0.047	0.125	16	0.264	0.023	0.041	0.125
	20	0.225	0.022	0.053	0.122	20	0.238	0.026	0.046	0.125
	24	0.224	0.022	0.053	0.123	24	0.235	0.028	0.047	0.125
	28	0.225	0.025	0.054	0.123	28	0.235	0.029	0.051	0.124
AT1-9	4	0.282	0.024	0.041	0.121	4	0.241	0.024	0.046	0.125
	8	0.295	0.021	0.035	0.120	8	0.236	0.023	0.052	0.125
	12	0.285	0.016	0.048	0.125	12	0.238	0.024	0.052	0.125
	16	0.296	0.031	0.038	0.125	16	0.288	0.022	0.046	0.125
	20	0.310	0.029	0.036	0.124	20	0.250	0.027	0.046	0.125
AT1-9	24	0.280	0.030	0.037	0.126	24	0.250	0.028	0.047	0.124
(Cont'd)	28	0.240	0.028	0.051	0.125	28	0.241	0.028	0.049	0.123
TC-7	0-1/4	0.282	0.018	0.026	0.106	1/2	0.269	0.023	0.041	0.132
	2-1/4	0.292	0.024			2-1/4	0.258	0.026		
	3-1/4	0.251	0.030			4			0.043	0.125
	4	0.255	0.028	0.029	0.106	4-1/2	0.250	0.024		
	5-5/8	0.282	0.019			7	0.280	0.021		
	7-1/8	0.270	0.031			7-1/4	0.310	0.031		
	8	0.291	0.021	0.043	0.122	8			0.035	0.120
	10	0.268	0.022			8-1/2	0.270	0.033		
	12	0.255	0.029	0.032	0.112	10	0.255	0.025		
	14-3/4	0.285	0.020			12			0.033	0.115
	16	0.290	0.019	0.042	0.117	12-1/2	0.270	0.030		
	17	0.265	0.040			14-1/4	0.270	0.029		
						16			0.033	0.125
						16-1/2	0.270	0.031		
TC-8	1/2	0.264	0.029	0.019	0.116	1/2	0.318	0.019	0.031	0.125
	4	0.289	0.040	0.020	0.116	4	0.275	0.025	0.031	0.125
	8	0.260	0.025	0.018	0.118	8	0.304	0.023	0.033	0.120
	12	0.290	0.023	0.039	0.116	12	0.265	0.016	0.031	0.135
	16	0.304	0.040	0.042	0.116	16	0.306	0.040	0.031	0.135
TC-9	1/2	0.265	0.026	0.036	0.125	1/2	0.235	0.028	0.033	0.131
	4	0.250	0.027	0.027	0.115	4	0.245	0.028	0.041	0.125
	8	0.255	0.029	0.027	0.125	8	0.265	0.027	0.038	0.125
	12	0.260	0.027	0.030	0.120	12	0.245	0.012	0.034	0.120
	16	0.255	0.025	0.034	0.124	16	0.292	0.014	0.035	0.125
TC-10	1/2	0.275	0.031	0.026	0.121	1/2	0.250	0.018	0.028	0.125
	4	0.250	0.027	0.029	0.120	4	0.265	0.018	0.042	0.125
	8	0.285	0.031	0.027	0.120	8	0.275	0.017	0.044	0.120
	12	0.265	0.031	0.028	0.120	12	0.235	0.029	0.038	0.124
	16	0.260	0.033	0.022	0.120	16	0.255	0.033	0.033	0.125
TC-11	1/2	0.275	0.035	0.021	0.120	1/2	0.285	0.020	0.024	0.125
	4	0.250	0.031	0.029	0.120	4	0.250	0.020	0.034	0.125
	8	0.270	0.031	0.030	0.120	8	0.250	0.019	0.033	0.125
	12	0.265	0.036	0.026	0.116	12	0.250	0.029	0.033	0.123
	16	0.265	0.032	0.026	0.115	16	0.246	0.030	0.035	0.125
TC-12	1/2	0.260	0.030	0.027	0.125	1/2	0.288	0.024	0.025	0.135
	4	0.260	0.033	0.028	0.125	4	0.275	0.023	0.037	0.135
	8	0.262	0.032	0.026	0.125	8	0.267	0.024	0.045	0.125
	12	0.263	0.030	0.031	0.120	12	0.240	0.026	0.035	0.124
	16	0.267	0.032	0.042	0.120	16	0.261	0.032	0.034	0.125

TABLE F-4. WELD DIMENSIONS FOR 0.187-INCH AND 0.50-INCH SQUARE BUTT WELDMENTS



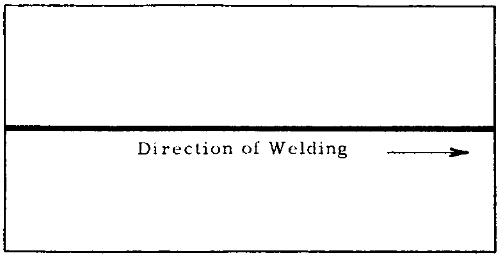


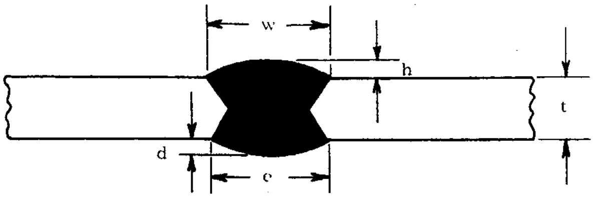
A - distance from start of weld

Panel No.	A	w	h	d	e
			Inches		
CT3-1	4	0.340	0.039	0.056	0.131
t = 0.187"	8	0.340	0.040	0.056	0.131
	12	0.340	0.039	0.061	0.130
	16	0.340	0.036	0.053	0.130
	20	0.340	0.040	0.048	0.125
	24	0.340	0.051	0.026	0.087
	28	0.340	0.046	0.034	0.100
	32	0.340	0.038	0.053	0.120
CT4-1	4	0.357	0.040	0.051	0.132
t = 0.187"	8	0.353	0.040	0.052	0.125
	12	0.353	0.036	0.052	0.125
	16	0.353	0.037	0.052	0.120
	20	0.353	0.041	0.044	0.121
	24	0.353	0.039	0.044	0.118
	28	0.350	0.040	0.047	0.118
	32	0.350	0.036	0.054	0.120
CT5-5	4	0.315	0.049	0.034	0.115
t = 0.187"	8	0.330	0.050	0.039	0.116
	12	0.331	0.053	0.033	0.106
	16	0.331	0.048	0.040	0.113
	20	0.325	0.055	0.027	0.100
	24	0.331	0.051	0.033	0.113
	28	0.345	0.050	0.034	0.118
	32	0.345	0.048	0.044	0.120
CM3-1	4	0.495	0.077	0.055	0.115
t = 0.187"	8	0.480	0.082	0.051	0.115
	12	0.467	0.084	0.048	0.115
	16	0.510	0.077	0.052	0.115
	20	0.495	0.076	0.054	0.141
	24	0.495	0.083	0.047	0.120
	28	0.495	0.083	0.052	0.120
	32	0.495	0.088	0.049	0.115
CM4-1	4	0.510	0.086	0.054	0.120
t = 0.187"	8	0.500	0.082	0.050	0.110
	12	0.500	0.088	0.049	0.110
	16	0.527	0.081	0.053	0.120
	20	0.510	0.077	0.053	0.131
	24	0.510	0.081	0.045	0.120
	28	0.520	0.087	0.046	0.120
	32	0.520	0.088	0.050	0.110

Panel No.	A	w	h	d	e
			Inches		
CM5-2	4	0.492	0.076	0.054	0.125
t = 0.187"	8	0.461	0.081	0.051	0.118
	12	0.486	0.078	0.059	0.118
	16	0.520	0.081	0.050	0.125
	20	0.476	0.072	0.053	0.135
	24	0.495	0.083	0.046	0.125
	28	0.480	0.085	0.046	0.125
	32	0.503	0.077	0.049	0.113
CT3-2	2.5			0.052	0.492
t = 0.50"	4	0.500	0.066		
	8	0.500	0.067		
	12	0.510	0.070		
	14			0.050	0.490
	16	0.510	0.069		
	18			0.058	0.490
	20	0.510	0.066		
	22			0.057	0.490
	24	0.510	0.069		
	26			0.057	0.490
	28	0.510	0.069		
	30			0.057	0.490
	32	0.510	0.066		
	34			0.068	0.490
CT4-2	4	0.495	0.063	0.058	0.510
t = 0.50"	8	0.495	0.070	0.050	0.515
	12	0.495	0.070	0.049	0.515
	16	0.495	0.067	0.059	0.510
	20	0.495	0.066	0.056	0.515
	24	0.495	0.067	0.056	0.510
	28	0.495	0.067	0.058	0.500
	32	0.495	0.067	0.060	0.500
CT5-6	4	0.450	0.065	0.051	0.545
t = 0.50"	8	0.450	0.066	0.054	0.535
	12	0.475	0.061	0.045	0.535
	16	0.470	0.057	0.052	0.505
	20	0.470	0.056	0.056	0.505
	24	0.470	0.062	0.056	0.505
	28	0.470	0.062	0.050	0.505
	32	0.475	0.046	0.050	0.505

TABLE F-5. WELD DIMENSIONS FOR 0.50-INCH AND 1.00-INCH DOUBLE V WELDMENTS





A = distance from start of weld

Panel No.	A	w	h	d	e
			Inches		
CT3-3	4	0.475	0.070	0.057	0.480
t = 1.00"	8	0.500	0.075	0.067	0.490
	12	0.525	0.078	0.061	0.500
	16	0.520	0.052	0.029	0.480
	20	0.525	0.052	0.020	0.480
	24	0.525	0.049	0.032	0.500
	28	0.520	0.066	0.030	0.480
	32	0.525	0.067	0.039	0.480
CT3-4	4	0.475	0.046	0.050	0.395
t = 0.50"	8	0.475	0.045	0.049	0.395
	12	0.512	0.049	0.045	0.400
	16	0.512	0.042	0.045	0.400
	20	0.520	0.042	0.044	0.410
	24	0.520	0.049	0.046	0.410
	28	0.510	0.050	0.042	0.410
	32	0.525	0.044	0.049	0.410
CT4-3	4	0.500	0.025	0.029	0.475
t = 1.00"	8	0.510	0.035	0.040	0.515
	12	0.510	0.039	0.047	0.500
	16	0.493	0.033	0.050	0.500
	20	0.500	0.029	0.046	0.500
	24	0.500	0.028	0.044	0.500
	28	0.500	0.026	0.038	0.500
	32	0.510	0.032	0.043	0.525
CT4-4	4	0.479	0.038	0.041	0.400
t = 0.50"	8	0.490	0.034	0.043	0.400
	12	0.475	0.036	0.047	0.402
	16	0.486	0.032	0.043	0.400
	20	0.475	0.045	0.046	0.400
	24	0.495	0.040	0.045	0.400
	28	0.484	0.037	0.048	0.390
	32	0.490	0.039	0.041	0.400
CT5-7	4	0.500	0.065	0.077	0.537
t = 1.00"	8	0.485	0.074	0.099	0.525
	12	0.473	0.020	0.044	0.525
	16	0.500	0.019	0.043	0.550
	20	0.500	0.019	0.040	0.555
	24	0.513	0.027	0.040	0.538
	28	0.525	0.039	0.037	0.526
	32	0.525	0.038	0.027	0.520
CT5-8	4	0.422	0.058	0.026	0.370
t = 0.50"	8	0.455	0.040	0.030	0.396
	12	0.507	0.049	0.030	0.396
	16	0.495	0.049	0.030	0.396
	20	0.520	0.046	0.035	0.396
	24	0.500	0.054	0.036	0.396
	28	0.475	0.045	0.037	0.396
	32	0.492	0.043	0.039	0.396

Panel No.	A	w	h	d	e
			Inches		
CM3-2	4	0.655	0.067	0.100	0.691
t = 0.50"	8	0.610	0.070	0.102	0.675
	12	0.610	0.068	0.098	0.665
	16	0.610	0.066	0.098	0.665
	20	0.625	0.062	0.096	0.690
	24	0.610	0.075	0.094	0.680
	28	0.610	0.075	0.098	0.690
	32	0.624	0.079	0.101	0.680
CM3-3	4	0.980	0.076	0.950	0.099
t = 1.00"	8	0.975	0.080	0.950	0.098
	12	0.975	0.079	0.955	0.096
	16	0.965	0.079	0.950	0.097
	20	0.970	0.079	0.950	0.098
	24	0.965	0.079	0.950	0.101
	28	0.965	0.077	0.950	0.088
	31	0.965	0.069	0.950	0.086
CM4-2	4	0.635	0.082	0.041	0.580
t = 0.50"	8	0.670	0.087	0.043	0.580
	12	0.650	0.067	0.040	0.580
	16	0.640	0.081	0.042	0.580
	20	0.610	0.079	0.052	0.617
	24	0.650	0.084	0.051	0.617
	28	0.625	0.071	0.054	0.617
	32	0.605	0.071	0.049	0.625
CM4-3	4	0.975	0.043	0.085	1.000
t = 1.00"	8	0.990	0.053	0.101	0.975
	12	1.029	0.058	0.094	0.975
	16	1.024	0.070	0.086	0.975
	20	1.024	0.063	0.094	0.960
	24	1.015	0.063	0.094	0.970
	28	1.010	0.052	0.090	0.970
	32	0.990	0.044	0.080	0.970
CM5-1	4	0.625	0.082	0.104	0.661
t = 0.50"	8	0.625	0.098	0.103	0.675
	9.5	0.590	0.081		
	12	0.605	0.084	0.103	0.695
	16	0.600	0.087	0.102	0.685
	20	0.586	0.086	0.103	0.690
	24	0.600	0.095	0.117	0.690
	28	0.640	0.088	0.104	0.690
	32	0.660	0.091	0.099	0.710
CM5-3	4	0.950	0.052	0.074	0.950
t = 1.00"	8	0.983	0.082	0.080	0.958
	12	0.955	0.072	0.094	0.960
	16	0.975	0.084	0.099	0.960
	20	0.975	0.088	0.077	0.985
	24	0.975	0.082	0.098	0.970
	28	0.975	0.068	0.110	0.975
	32	0.975	0.069	0.089	0.965

APPENDIX G

PHASE I BULGE TEST, TENSILE TEST, CYLINDER TEST AND MIT TEST DATA

(Contract No. NAS8-20160)

TABLE G-1.

1:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR 2219-T87 PARENT METAL PANELS

Panel No.	Pressure, psi	Height, in.	Gage Angle[a]	Surface Microstrain at Various Positions[b]			
				0	1/2 in.	2 in.	6 in.
A-1	40	0.55	0	1730	(c)	1770	2110
			120	1750		1710	1440
			240	1640		1610	1330
	112	0.85	0	3420	(c)	3500	3930
			120	3290		3180	2670
			240	2970		2940	2220
	208	1.13	0	6060	(c)	6090	6250
			120	5750		5440	4430
			240	4990		4950	3500
	240	1.23	0	7480	(c)	7500	7090
			120	6850		6520	5150
			240	5960		5900	4030
	268	1.33	0	8940	(c)	9000	7970
			120	8040		7550	5920
			240	6920		6830	4590
A-2	8	0.30	0	673	(c)	711	704
	26	0.51	0	1385	(c)	1456	1570
	96	0.83	0	2680	(c)	2970	-
A-3	40	0.54	0	1640	1680	1710	2020
	112	0.80	0	3210	3260	3320	3840
	144	0.90	0	3820	3910	3950	4550
	232	1.20	0	6230	6380	6480	6700
	286	1.40	0	8320	8510	8720	8700

(a) Angle of strain gage element to reference axis, degrees.
(b) Distance of strain gage from center of panel.
(c) Strain gage was not placed at this position.

TABLE G-2.

1:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR TIG 2219-T87/2319 SINGLE-WELD PANELS

Panel No.	Pressure, psi	Height, in.	Parent Metal Microstrain		Weld Metal Microstrain		
			Angle[a]	2 in. from Center	Angle[a]	Center	2 in. from Center
AT1-2	40	0.70	45	1740	0	1, 760	-
			165	1600	90	2, 940	2, 410
			285	1920			
	89	1.03	45	2590	0	2, 890	-
			165	2360	90	10, 900	11, 000
			285	2590			
	164	1.33	45	3920	0	-	-
			165	3650	90	-	-
			285	3720			
AT1-3	50	0.81	45	1820	0	2, 020	1, 840
			165	1790	90	3, 370	-
			285	1950			
	85	1.0[b]	45	2460	0	2, 610	2, 520
			165	2470	90	10, 800	-
			285	2510			
	158	1.3[b]	45	3630	0	-	-
			165	3730	90	-	-
			285	3480			
AT1-7	41	0.70	45	1810	0	2, 010	1, 820
			165	1680	90	1, 920	1, 610
			285	1890			
	93	1.00	45	2750	0	3, 710	3, 050
			165	2770	90	6, 220	5, 890
			285	2790			
	165	1.31	45	3730	0	6, 180	4, 570
			165	3830	90	18, 400	20, 900
			285	3710			

(a) Angle of strain gage element to reference axis through weld, degrees.
(b) Estimated value. Deflectometer inoperative.

TABLE G-3.

1:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR TIG 2219-T87/2319 CROSS-WELD PANELS

Panel No.	Pressure, psi	Height, in.	Parent Metal Microstrain		Weld Metal Microstrain		
			Angle(a)	2 In. from Center	Angle(a)	Center	2 In. from Center
AT1-1	45	0.60	45	1670	0	2, 200	1, 740
			165	1620	90	4, 780	1, 950
			285	1700			
	81	0.80	45	2370	0	12, 200	2, 660
			165	2320	90	9, 860	4, 780
			285	2380			
	150	1.10	45	3450	0	-	3, 820
			165	3310	90	-	10, 500
			285	3390			
AT1-8	42	0.82	45	1590	0	2, 290	1, 970
			165	1610	90	3, 210	-
			285	1900			
	80	1.02	45	2340	0	5, 590	2, 770
			165	2310	90	7, 070	-
			285	2750			
	142	1.30	45	3350	0	-	4, 140
			165	3170	90	-	-
			285	3740			
AT1-9	48	0.71	45	1800	0	3, 960	1, 850
			165	1970	90	3, 840	1, 450
			285	1550			
	80	0.90	45	2420	0	8, 340	2, 500
			165	2600	90	7, 520	3, 180
			285	2020			
	140	1.20	45	3500	0	-	3, 240
			165	3550	90	-	8, 690
			285	2780			

(a) Angle of strain gage element to reference axis through one of the welds, degrees.

TABLE G-4.

1:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR 2219-T87 PARENT METAL PANELS WITH A REDUCED CENTER SECTION

Panel No.	Pressure, psi	Height, in.	Full Thickness Microstrain		Reduced Section Microstrain	
			Angle(a)	2 In. from Center	Angle(a)	Center
A-8	40	0.62	0	1880	0	2, 220
			120	1800	120	2, 220
			240	1880	240	2, 340
	108	0.91	0	3230	0	3, 910
			120	3140	120	3, 800
			240	3300	240	4, 020
	220	1.30	0	5320	0	-
			120	6050	120	-
			240	6210	240	-
A-9	33	0.55	0	1660	0	2, 340
			120	1540	120	2, 130
			240	1470	240	2, 030
	120	0.95	0	3410	0	6, 950
			120	3350	120	5, 430
			240	3160	240	5, 020
	220	1.32	0	5520	0	24, 700
			120	6210	120	16, 200
			240	5600	240	12, 700
A-25	39	0.63	0	1690	0	2, 950
			120	1780	120	3, 080
			240	1770	240	3, 000
	104	0.92	0	3220	0	6, 700
			120	3280	120	7, 140
			240	3340	240	7, 300
	210	1.30	0	4950	0	19, 800
			120	6570	120	-
			240	6860	240	-

(a) Angle of strain gage element to reference axis, degrees.

TABLE G-5.

1:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR 2219-T87 PARENT METAL PANELS WITH A MACHINED GROOVE

Panel No.	Pressure, psi	Height, in.	Full Thickness Microstrain		Reduced Section Microstrain		
			Angle(a)	2 In. from Center	Angle(a)	Center	2 In. from Center
A-13	38	0.52	45 165 285	1540 - 1560	0 90	1, 440 2, 700	- 2, 640
	78	0.71	45 165 285	2410 - 2410	0 90	2, 370 5, 420	- 4, 770
	125	0.90	45 165 285	3020 - 3180	0 90	3, 220 39, 300	- 28, 300
A-14	46	0.65	45 165 285	1920 1960 2000	0 90	1, 790 4, 210	- -
	98	0.90	45 165 285	2910 3020 3120	0 90	3, 000 12, 600	- -
	154	1.10	45 165 285	3680 3770 4270	0 90	4, 700 -	- -
A-15	32	0.62	45 165 285	1670 1720 1690	0 90	1, 540 3, 360	- -
	74	0.83	45 165 285	2570 2590 2640	0 90	2, 460 6, 600	- -
	118	1.01	45 165 285	3290 3450 3370	0 90	3, 940 32, 800	- -

(a) Angle of strain gage element to reference axis through groove, degrees.

TABLE G-6.

1:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR 2219-T87 PARENT METAL PANELS WITH A MACHINED CROSS GROOVE

Panel No.	Pressure, psi	Height, in.	Full Thickness Microstrain		Reduced Section Microstrain		
			Angle(a)	2 In. from Center	Angle(a)	Center	2 In. from Center
A-16	41	0.53	45 165 285	1570 1570 1620	0 90	2170 2660	1, 440 2, 960
	78	0.72	45 165 285	2380 2430 2550	0 90	3630 4670	2, 310 5, 520
	148	1.00	45 165 285	3570 3710 3790	0 90	- -	- -
A-17	48	0.62	45 165 285	2060 1780 1770	0 90	3060 3100	1, 830 4, 220
	92	0.82	45 165 285	2990 2550 2600	0 90	6020 6500	2, 830 10, 700
	132	1.00	45 165 285	3690 3180 3240	0 90	- -	4, 020 37, 400
A-18	44	0.62	45 165 285	1710 1880 1920	0 90	2720 2820	1, 720 3, 880
	84	0.81	45 165 285	2470 2740 2880	0 90	4620 5820	2, 730 9, 370
	126	1.00	45 165 285	3080 3420 3580	0 90	- -	4, 360 43, 000

(a) Angle of strain gage element to reference axis through one of grooves, degrees.

TABLE G-7.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT - STRAIN DATA FOR 2219-T87 PARENT METAL PANELS

Nominal Height, in.	Spec. No. A-1			Spec. No. A-2			Spec. No. A-3		
	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.
0.3	0.35	14	930	0.30	8	711	0.33	12	840
0.4	0.46	24	1, 295	0.41	16	1050	0.42	22	1190
0.5	0.55	40	1, 700	0.51	26	1460	0.54	40	1710
0.6	0.65	64	2, 240	0.62	45	1920	0.64	61	2250
0.7	0.74	80	2, 630	0.73	70	2440	0.73	84	2740
0.8	0.85	112	3, 210	0.83	96	2970	0.83	112	3320
0.9	0.94	144	3, 860	0.92	124	3410	0.93	144	3950
1.0	1.03	176	4, 560	1.00	132	3880	1.03	175	4660
1.1	1.13	208	5, 490	-	-	-	1.14	208	5580
1.2	1.23	240	6, 670	1.20	220	-	1.22	232	6480
1.3	1.33	268	7, 780	-	-	-	1.33	258	7640
1.4	1.44	302	9, 180	1.40	276	-	1.42	286	8720
1.5	1.55	334	10, 500	-	-	-	1.52	325	-
1.6	1.63	360	-	1.60	332	-	-	-	-
1.7	1.73	380	-	-	-	-	1.72	400	-
1.8	1.83	410	-	1.80	390	-	-	-	-
1.9	1.93	440	-	-	-	-	-	-	-
2.0	2.03	464	-	2.00	448	-	2.00	480	-
2.1	2.15	500	-	-	-	-	-	-	-

(a) Average of three elements of a strain gage rosette at the 2-in. from center position.

TABLE G-8.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT - STRAIN DATA FOR TIG 2219-T87/2319 SINGLE WELD PANELS

Nominal Height, in.	Spec. No. AT1-2			Spec. No. AT1-3			Spec. No. AT1-7		
	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.
0.5	0.50	16	1040	0.50	19	1000	0.50	18	1130
0.6	0.60	26	1340	0.61	31	1600	0.60	28	1450
0.7	0.70	40	1750	0.73	43	1690	0.70	41	1790
0.8	0.80	53	1930	0.81	50	1850	0.81	57	2120
0.9	0.90	68	2160	0.90	60	2100	0.91	76	2470
1.0	1.03	89	2510	1.00	85	2480	1.00	93	2770
1.1	1.13	110	2880	1.10	109	2890	1.11	116	3110
1.2	1.23	135	3250	1.20	131	3210	1.20	140	3390
1.3	1.33	164	3760	1.30	158	3610	1.31	165	3760
Failure	1.35	176	-	1.35	172	-	1.42	192	-

(a) Average of three elements of a strain gage rosette at the 2-in. from center position.

TABLE G-9.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT - STRAIN DATA FOR TIG 2219-T87/2319 CROSS-WELD PANELS

Nominal Height, in.	Spec. No. AT1-1			Spec. No. AT1-8			Spec. No. AT1-9		
	h, in.	p psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.
0.5	0.51	32	1310	0.50	8	685	0.51	24	1140
0.6	0.61	45	1660	0.60	15	960	0.61	34	1440
0.7	0.71	63	2030	0.72	27	1370	0.71	48	1770
0.8	0.80	81	2360	0.82	42	1700	0.81	64	2070
0.9	0.90	102	2700	0.91	58	2090	0.90	80	2350
1.0	1.00	126	3080	1.02	80	2470	1.00	98	2630
1.1	1.11	150	3380	1.11	97	2690	1.09	116	2940
1.2	-	-	-	1.21	121	3110	1.20	140	3280
1.3	-	-	-	1.30	142	3420	-	-	-
Failure	1.15	161	-	1.35	156	-	1.26	158	-

(a) Average of three elements of a strain gage rosette at the 2-in. from center position.

TABLE G-10.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT - STRAIN DATA FOR 2219-T87 PARENT METAL PANELS WITH A MACHINED GROOVE

Nominal Height, in.	Spec. No. A-13			Spec. No. A-14			Spec. No. A-15		
	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.	h, in.	p, psi	$\epsilon^{(a)}$ µin./in.
0.3	0.30	10	740	0.32	8	790	0.31	4	610
0.4	-	-	-	-	-	-	0.41	10	910
0.5	0.52	38	1550	0.55	30	1540	0.52	20	1290
0.6	0.62	57	2035	0.65	46	1970	0.62	32	1690
0.7	0.71	78	2410	0.72	64	2350	0.72	50	2120
0.8	0.80	102	2825	0.80	83	2740	0.83	74	2600
0.9	0.90	125	3100	0.90	98	3020	0.92	96	3010
1.0	-	-	-	1.00	124	3420	1.01	118	3370
1.1	-	-	-	1.10	154	3910	-	-	-
Failure	0.95	140	-	1.16	176	-	1.11	150	-

(a) Average of three elements of a strain gage rosette at the 2-in. from center position.

TABLE G-11.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT - STRAIN DATA FOR 2219-T87 PARENT METAL PANELS WITH A MACHINED CROSS GROOVE

Nominal Height, in.	Spec. No. A-16			Spec. No. A-17			Spec. No. A-18		
	h, in.	p, psi	$\epsilon^{(a)}$ μin./in.	h, in.	p, psi	$\epsilon^{(a)}$ μin./in.	h, in.	p, psi	$\epsilon^{(a)}$ μin./in.
0.3	0.32	14	770	0.32	12	730	0.30	10	660
0.4	-	-	-	0.41	19	1040	0.42	18	1030
0.5	0.53	41	1590	0.53	31	1460	0.52	29	1420
0.6	0.63	58	2020	0.62	48	1870	0.62	44	1840
0.7	0.72	78	2450	0.73	69	2310	0.72	64	2270
0.8	0.82	106	2840	0.82	92	2710	0.81	84	2700
0.9	0.92	132	3240	0.91	114	3060	0.90	102	3010
1.0	1.00	148	3690	1.00	132	3370	1.00	126	3360
1.1	1.12	180	3990	1.13	162	3730	-	-	-
Failure	1.15	192	-	1.15	172	-	1.10	146	-

(a) Average of three elements of a strain gage rosette at the 2-inch from center position.

TABLE G-12.

1:1 HYDRAULIC BULGE TEST BENDING STRAIN ANALYSIS DATA FOR 2219-T87 AND 2014-T6 PARENT METAL PANELS

Nominal Height, in.	Spec. No. A-2(2219-T87)				Spec. No. B-1 (2014-T6)			
	h, in.	p, psi	$\epsilon_t^{(a)}$ μin./in.	$\epsilon_b^{(b)}$ μin./in.	h, in.	p, psi	$\epsilon_t^{(a)}$ μin./in.	$\epsilon_b^{(b)}$ μin./in.
0.3	0.30	8	711	314	-	-	-	-
0.4	0.41	16	1052	380	-	-	-	-
0.5	0.51	26	1456	459	0.50	6	920	495
0.6	0.62	45	1920	510	0.62	14	1285	495
0.7	0.73	70	2440	600	0.70	24	1740	594
0.8	0.83	96	2970	645	0.83	40	1990	592
0.9	0.92	124	3410	660	0.90	60	2545	680
1.0	1.00	132	3880	705	1.00	80	3095	745
1.1	-	-	-	-	1.10	108	3490	810
1.2	-	-	-	-	1.20	136	3955	855
1.3	-	-	-	-	1.30	168	4480	918
1.4	-	-	-	-	1.39	202	5215	995
1.5	-	-	-	-	1.50	240	6050	1115
1.6	-	-	-	-	1.60	265	6900	1140

(a) Total outer fiber surface strain.
(b) Bending strain.

TABLE G-13.

2:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR 2219-T87 PARENT METAL PANELS

Panel No.	Pressure, psi	Height, in.	Gage Angle(a)	Surface Microstrain at Various Positions(b)			
				0	1 In. Normal to Ref. Axis	2 In. Along Ref. Axis	2 In. Normal to Ref. Axis
A-4	75	0. 50	0 120 240	3, 000 2, 210 2, 120	3, 000 2, 220 2, 150	(c)	2960 2110 2090
	240	0. 92	0 120 240	6, 310 5, 310 4, 950	6, 160 5, 310 4, 960	(c)	6140 5000 4910
	320	1. 13	0 120 240	8, 150 7, 840 7, 140	7, 980 7, 850 7, 170	(c)	7860 7340 7020
	360	1. 20	0 120 240	8, 920 8, 870 8, 130	8, 730 8, 910 8, 140	(c)	8520 8350 7960
	410	1. 30	0 120 240	10, 000 10, 200 9, 480	9, 500 10, 100 9, 360	(c)	9550 9850 9520
A-5	72	0. 51	0 90	2, 750 1, 710	(c)	(c)	(c)
	106	0. 60	0 90	3, 420 2, 200	(c)	(c)	(c)
	156	0. 70	0 90	4, 330 -	(c)	(c)	(c)
A-6	65	0. 51	0 90	2, 660 1, 570	(c)	2670 1590	2680 1600
	130	0. 70	0 90	4, 130 2, 630	(c)	4150 2630	4160 2680
	270	1. 02	0 90	7, 230 4, 920	(c)	7120 5040	7280 5190
	300	1. 10	0 90	8, 160 -	(c)	8180 6040	8400 6220
	340	1. 22	0 90	- -	(c)	- -	9920 7750

(a) Angle of strain gage element to reference axis, degrees.
(b) Distance of strain gage from center of panel, inches.
(c) Strain gage was not placed at this position.

TABLE G-14.

2:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR TIG 2219-T87/2319 SINGLE-WELD PANELS

Panel No.	Pressure, psi	Height, in.	Parent Metal Microstrain		Weld Metal Microstrain(b)		
			Angle(a)	2 In. from Center	Angle(a)	Center	2 In. from Center
AT1-10	50	0. 50	0 120 240	2260 1340 1295	0 90	3, 760 1, 010	2, 840 980
	94	0. 70	0 120 240	2800 2060 1960	0 90	8, 000 1, 635	5, 590 1, 700
	144	0. 90	0 120 240	3040 2940 2820	0 90	11, 700 2, 690	7, 780 2, 710
AT1-11	56	0. 51	0 120 240	2390 1400 1535	0 90	2, 380 1, 140	2, 710 1, 135
	105	0. 70	0 120 240	3270 1910 2150	0 90	6, 430 1, 660	9, 170 1, 570
	164	0. 90	0 120 240	3860 2570 2920	0 90	- 2, 380	- -
AT1-12	58	0. 50	0 120 240	2560 1320 1500	0 90	3, 490 934	3, 750 1, 340
	108	0. 70	0 120 240	3400 1890 2100	0 90	8, 590 1, 340	9, 970 2, 040
	158	0. 90	0 120 240	3870 2650 2820	0 90	- 1, 940	17, 100 3, 070

(a) Angle of strain gage element to reference axis, degrees.
(b) Weld at 90° to reference axis.

TABLE G-15.

2:1 HYDRAULIC BULGE TEST STRESS ANALYSIS DATA FOR TIG 2219-T87/2319 CROSS WELD PANELS

Panel No.	Pressure, psi	Height, in.	Parent Metal Microstrain		Weld Metal Microstrain[b]		
			Angle[a]	2 In. from Center	Angle[a]	Center	2 In. from Center
AT1-4	25	0.30	0 120 240	1630 1030 864	0 90	2,550 1,590	(c) (c)
	78	0.51	0 120 240	3000 1830 1720	0 90	8,410 6,090	- -
	150	0.72	0 120 240	4360 2510 2790	0 90	- -	- -
AT1-5	18	0.30	0 120 240	1580 805 670	0 90	2,960 740	717 528
	56	0.50	0 120 240	2850 1235 1170	0 90	7,780 2,100	3140 990
	104	0.70	0 120 240	3770 1660 1830	0 90	15,100 5,900	3660 1560
AT1-6	22	0.34	0 120 240	2015 835 750	0 90	2,670 320	818 576
	49	0.51	0 120 240	2820 1320 1200	0 90	5,030 810	2210 1000
	87	0.71	0 120 240	3270 1920 1960	0 90	8,020 3,240	4750 2040

(a) Angle of strain gage element to reference axis, degrees.
(b) Reference axis along short weld.
(c) Strain gage was not placed at this position.

TABLE G-16.

2:1 HYDRAULIC BULGE TEST BENDING STRAIN ANALYSIS DATA FOR 2219-T87 AND 2014-T6 PARENT METAL PANELS

Nominal Height, in.	Spec. No. A-5 (2219-T87)				Spec. No. B-6 (2014-T6)			
	h, in.	Angle(a)	ϵ_t(b) µin./in.	ϵ_b(c) µin./in.	h, in.	Angle(a)	ϵ_t(b) µin./in.	ϵ_b(c) µin./in.
0.3	0.30	0 90	1260 727	585 344	0.32	0 90	650 256	265 160
0.4	0.41	0 90	1980 1180	705 416	0.42	0 90	1120 376	454 243
0.5	0.51	0 90	2750 1710	780 524	0.51	0 90	1645 550	595 225
0.6	0.60	0 90	3420 2200	840 662	0.63	0 90	2260 982	720 318
0.7	0.70	0 90	4330 -	960 -	0.72	0 90	2600 1360	905 390
0.8	-	-	-	-	0.81	0 90	2840 1850	992 410
0.9	-	-	-	-	0.93	0 90	3090 2530	1180 500
1.0	-	-	-	-	1.01	0 90	3450 3230	1300 580
1.1	-	-	-	-	1.10	0 90	3800 3640	1440 450
1.2	-	-	-	-	1.20	0 90	4170 4850	1600 710
1.3	-	-	-	-	1.30	0 90	4590 5890	1800 815
1.4	-	-	-	-	1.41	0 90	4900 7200	1990 950

(a) Angle of strain gage element to reference axis (short dimension of panel), degrees.
(b) Total outer fiber surface strain.
(c) Bending strain.

TABLE G-17.

2:1 HYDRAULIC BULGE TEST RESULTS USING TENSILE MACHINE INSTEAD OF BOLTS TO HOLD TEST DIE TOGETHER, 2219-T87 PARENT METAL SPECIMEN NO. A-29

Nominal Height, in.	Actual h, in.	Applied Pressure, psi	Surface Microstrain Across Major Diameter	Surface Microstrain Across Minor Diameter
0.3	0.35	16	605	535
0.4	0.41	25	722	764
0.5	0.52	40	937	1240
0.6	0.60	58	1030	1690
0.7	0.72	80	1330	2340
0.8	0.81	108	1450	2910
0.9	0.92	130	1820	3650
1.0	1.01	165	1890	4460
1.1	1.11	200	2240	5410
1.2	1.21	225	2230	6640
1.3	1.31	250	2460	8000
1.4	1.40	280	2870	9880

TABLE G-18.

PHASE I UNIAXIAL TENSILE TEST RESULTS ON 2219-T87 PARENT METAL

Material & Process	Sheet No.	Specimen No.	Yield Strength 0.2% Offset, ksi	Ultimate Strength, ksi	Elongation in 2 In., %
2219-T87 Parent Metal	2A	1	52.5	65.0	9.8
		2	52.5	64.8	10.5
		3	53.9	65.8	11.2
		4	53.9	65.6	11.2
		5	53.7	65.3	11.2
	7A	1	54.1	65.8	11.3
		2	54.0	65.5	11.3
		3	53.7	65.4	10.3
		4	53.9	65.4	10.4
		5	54.1	65.0	10.4
	8A	1	54.7	66.7	10.5
		2	54.5	66.7	10.3
		3	54.8	66.6	11.0
		4	54.7	66.7	11.0
		5	54.6	66.8	10.7

TABLE G-19.

PHASE I UNIAXIAL TENSILE TEST RESULTS ON 2219-T87 WELDMENTS FOR 1:1 BULGE TESTS

Material & Process	Panel No.	Specimen No.	Yield Strength 0.2% Offset, ksi	Ultimate Strength, ksi	Elongation in 2 In., %
TIG 2219-T87 2319	AT1-2	1	30.4	39.7	1.0
		2	30.1	39.5	1.1
		3	31.1	39.8	1.4
		4	29.8	39.2	1.1
		5	28.7	38.7	1.3
	AT1-3	1	29.3	44.9	2.3
		2	26.7	44.0	2.5
		3	27.3	43.0	2.2
		4	27.1	43.7	2.7
		5	26.3	43.3	2.6
	AT1-7	1	29.3	42.9	2.2
		2	29.5	43.3	2.0
		3	28.6	41.9	1.5
		4	28.0	41.3	1.8
		5	29.4	42.9	1.8
	AT1-1	1	31.0	44.8	2.2
		2	30.7	43.8	2.0
		3	29.7	43.7	1.5
		4	30.9	44.3	2.1
		5	31.0	43.3	1.9
	AT1-8	1	29.2	38.3	1.8
		2	29.2	37.9	1.8
		3	30.4	40.5	1.5
		4	29.3	41.0	1.4
		5	29.2	40.0	2.0
	AT1-9	1	29.1	41.7	2.2
		2	28.8	42.2	1.9
		3	29.1	38.8	1.9
		4	28.6	40.9	2.0
		5	31.3	43.1	2.1

TABLE G-20.

PHASE I UNIAXIAL TENSILE TEST RESULTS ON 2219-T87 WELDMENTS FOR 2:1 BULGE TESTS

Material & Process	Panel No.	Specimen No.	Yield Strength 0.2% Offset, ksi	Ultimate Strength, ksi	Elongation in 2 In., %
TIG 2219-T87 2319	AT1-10	1	31.5	41.0	1.5
		2	30.0	39.9	1.8
		3	29.4	40.8	1.3
		4	29.7	42.8	1.8
		5	30.6	43.2	1.6
	AT1-11	1	35.0	44.3	1.0
		2	30.9	41.1	1.0
		3	30.9	41.0	1.0
		4	31.1	44.3	1.9
	AT1-12	1	32.6	43.5	1.4
		2	30.4	42.4	1.5
		3	30.6	40.2	1.3
		4	32.5	42.0	1.6
		5	31.8	42.0	1.4
	AT1-4	1	31.6	42.8	1.9
		2	33.1	43.1	1.6
		3	30.9	42.0	1.9
		4	31.4	41.9	1.9
		5	31.3	44.0	2.8
	AT1-5	1	29.5	39.1	1.3
		2	30.3	40.0	1.3
		3	31.9	41.2	1.4
		4	30.6	38.9	1.0
		5	30.8	40.9	1.2
	AT1-6	1	28.3	38.4	1.5
		2	29.0	38.9	1.5
		3	29.6	38.5	1.7
		4	29.6	39.7	2.0
		5	29.8	40.6	2.0

TABLE G-21.

MIT BIAXIAL SPECIMEN TEST DATA

Material & Process	Specimen No.	Test Section Stress-Strain Data			Ultimate Strength, ksi
		Stress, ksi	Longitudinal, μin. /in.	Transverse, μin. /in.	
2219-T87 Parent Metal	M-1	-	-	-	72.0
	M-2	-	-	-	71.4
	M-3	-	-	-	72.0
	M-4	-	-	-	68.5
	M-5	12.7	1, 125	-130	
		19.0	1, 670	-220	
		25.3	2, 200	-290	
		31.6	2, 710	-360	
		38.0	3, 320	-490	
		44.3	3, 880	-560	
		50.6	4, 670	-620	
		56.9	6, 860	-570	
		60.4	12, 350	-370	
		63.3	17, 650	-80	
		66.5	26, 350	+950	
		-	-	-	73.4

TABLE G-22.

SUMMARY OF CYLINDER TEST RESULTS

Test No.	Cylinder No.	Stress Ratio	Failure Pressure, psig	Remarks
1	XCY-1	2:1	545	Failed in heat-affected zone.
2	CY-1	2:1	595	Failed in heat-affected zone.
3	CY-4	1:0	570	Failed in heat-affected zone.
4	CY-5	1:1	575	Failed in heat-affected zone (secondary failure in rivets).
5	CY-2	2:1	572	Failed in heat-affected zone.
6	CY-10	2:1	575	Failed in heat-affected zone.
7	CY-11	1:1	540	Failed in heat-affected zone (secondary failure in rivets).
8	CY-12	1:1	542	Failed in heat-affected zone.
9	CY-13	1:0	575	Failed in heat-affected zone.
10	CY-16	1:0	575	Failed in heat-affected zone.
11	CY-14	2:1	1010	Failed in base metal at right edge of reinforcing patch.
12	CY-9	2:1	995	Failed in heat-affected zone when reinforcing patch blew off.
13	CY-15	2:1	1010	Failed in heat-affected zone when reinforcing patch blew off.
14A	CY-7	1:1	640	Failed in upper end rivet row.
14B	CY-7	1:1	450	Failed in rivets because of excessive leaking.
15	CY-6	1:1	-	Not tested.
16	CY-8	1:1	-	Not tested.

TABLE G-23. STRESS-STRAIN DATA ON CYLINDER NO. XCY-1 (2:1)

TEST NUMBER 1 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	305.	65.	11855.	3475.	3476.	1738.	1737.613	304.954	64.999	-129.483	3010.4	251.280	0.35
100.	555.	125.	23710.	6950.	6954.	3475.	3475.434	554.845	124.992	-237.943	6022.2	458.260	0.35
150.	805.	205.	35566.	10425.	10433.	5213.	5213.569	804.676	204.980	-353.380	9035.6	668.746	0.35
200.	1035.	250.	47421.	13900.	13914.	6950.	6951.737	1034.464	249.969	-449.552	12050.2	857.265	0.35
250.	1320.	320.	59276.	17375.	17398.	8688.	8690.280	1319.130	319.949	-573.678	15067.1	1093.380	0.35
300.	1625.	400.	71131.	20850.	20884.	10425.	10429.170	1623.681	399.919	-708.260	18086.0	1346.898	0.35
350.	1960.	465.	82987.	24325.	24373.	12163.	12168.156	1958.082	464.892	-848.041	21107.4	1621.229	0.35
400.	2290.	525.	94842.	27800.	27864.	13900.	13907.297	2287.381	524.862	-984.285	24130.7	1890.785	0.35
450.	2650.	590.	106697.	31275.	31358.	15638.	15646.726	2646.495	589.826	-1132.712	27156.7	2184.767	0.35

TEST NUMBER 1 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	605.	185.	11855.	3475.	3477.	1738.	1737.821	604.817	184.983	-276.430	3011.3	508.977	0.35
100.	1030.	305.	23718.	6950.	6957.	3475.	3476.060	1029.470	304.954	-467.048	6025.1	864.160	0.35
150.	1600.	440.	35566.	10425.	10442.	5213.	5214.793	1598.720	439.903	-713.518	9042.8	1334.973	0.35
200.	2250.	595.	47421.	13900.	13931.	6950.	6954.135	2247.473	594.823	-994.804	12064.8	1872.047	0.35
250.	3030.	820.	59276.	17375.	17428.	8688.	8694.624	3025.419	819.664	-1345.779	15092.8	2523.748	0.35
300.	4050.	985.	71131.	20850.	20934.	10425.	10435.269	4041.820	984.515	-1759.218	18129.8	3350.861	0.35
350.	5715.	1130.	82987.	24325.	24464.	12163.	12176.244	5698.731	1129.362	-2389.832	21186.5	4683.036	0.35
400.	9465.	1285.	94842.	27800.	28063.	13900.	13917.861	9420.487	1284.175	-3746.632	24303.6	7672.195	0.35
450.	13360.	1460.	106697.	31275.	31693.	15638.	15660.331	13271.541	1458.936	-5155.667	27447.4	10779.122	0.35

TEST NUMBER 1 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	710.	165.	11855.	3475.	3477.	1738.	1737.787	709.747	164.987	-306.157	3011.6	587.046	0.35
100.	1260.	290.	23718.	6950.	6959.	3475.	3476.008	1259.206	289.959	-542.208	6026.5	1041.050	0.35
150.	2035.	435.	35566.	10425.	10446.	5213.	5214.767	2032.932	434.906	-863.743	9046.7	1675.371	0.35
200.	3010.	525.	47421.	13900.	13942.	6950.	6953.649	3005.478	524.862	-1235.619	12074.0	2460.337	0.35
250.	4290.	655.	59276.	17375.	17450.	8688.	8693.190	4280.824	654.785	-1727.463	15111.8	3493.574	0.35
300.	6685.	745.	71131.	20850.	20989.	10425.	10432.767	6662.754	744.723	-2592.617	18177.4	5412.390	0.35
350.	10410.	735.	82987.	24325.	24578.	12163.	12171.439	10356.189	734.730	-3881.821	21285.7	8387.901	0.35
375.	12530.	710.	88914.	26063.	26389.	13031.	13040.502	12452.150	709.747	-4606.664	22854.1	10079.147	0.35

TEST NUMBER 1 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	550.	185.	11855.	3475.	3477.	1738.	1737.821	549.849	184.983	-257.191	3011.1	466.657	0.35
100.	950.	320.	23718.	6950.	6957.	3475.	3476.112	949.548	319.949	-444.324	6024.6	806.004	0.35
150.	1515.	460.	35566.	10425.	10441.	5213.	5214.898	1513.853	459.895	-690.812	9042.0	1273.272	0.35
200.	2235.	610.	47421.	13900.	13931.	6950.	6954.239	2232.505	609.814	-994.812	12064.7	1863.302	0.35
250.	3145.	790.	59276.	17375.	17430.	8688.	8694.363	3140.065	789.688	-1375.413	15094.5	2607.744	0.35
300.	4330.	980.	71131.	20850.	20940.	10425.	10435.216	4320.652	979.519	-1855.060	18134.8	3569.545	0.35
350.	6255.	1190.	82987.	24325.	24477.	12163.	12176.973	6235.519	1189.292	-2598.684	21197.9	5117.645	0.35
400.	9325.	1365.	94842.	27800.	28059.	13900.	13918.974	9281.790	1364.070	-3726.051	24300.3	7568.994	0.35
450.	12105.	1495.	106697.	31275.	31654.	15638.	15660.878	12032.320	1493.884	-4734.171	27413.3	9786.186	0.35

TABLE G-24. STRESS-STRAIN DATA ON CYLINDER NO. CY-1 (2:1)

TEST NUMBER 2 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	320.	75.	11855.	3475.	3476.	1738.	1737.630	319.949	74.997	-138.231	3010.4	264.742	0.35
100.	550.	135.	23710.	6950.	6954.	3475.	3475.469	549.849	134.992	-239.694	6022.2	456.039	0.35
150.	820.	175.	35566.	10425.	10434.	5213.	5213.412	819.664	174.984	-348.127	9035.7	675.441	0.35
200.	1190.	250.	47421.	13900.	13917.	6950.	6951.737	1189.292	249.969	-503.741	12052.1	979.429	0.35
250.	1470.	310.	59276.	17375.	17401.	8688.	8690.193	1468.920	309.952	-622.605	15069.3	1209.899	0.35
300.	1830.	385.	71131.	20850.	20888.	10425.	10429.014	1828.328	384.925	-774.639	18089.7	1505.799	0.35
350.	2160.	450.	82987.	24325.	24378.	12163.	12167.973	2157.670	449.899	-912.649	21111.6	1776.381	0.35
400.	2485.	490.	94842.	27800.	27869.	13900.	13906.811	2481.917	489.880	-1040.129	24135.3	2039.278	0.35
450.	2795.	535.	106697.	31275.	31362.	15638.	15645.866	2791.101	534.857	-1164.085	27160.7	2291.071	0.35
500.	3080.	660.	118552.	34750.	34857.	17375.	17386.467	3075.266	659.783	-1307.267	30187.1	2534.668	0.35
550.	3530.	725.	130407.	38225.	38360.	19113.	19126.357	3523.784	724.737	-1486.982	33220.7	2899.584	0.35

TEST NUMBER 2 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	115.	70.	11855.	3475.	3475.	1738.	1737.622	114.993	69.998	-64.747	3009.8	107.999	0.35
100.	215.	130.	23710.	6950.	6951.	3475.	3475.452	214.976	129.991	-120.739	6020.2	201.545	0.35
150.	305.	200.	35566.	10425.	10428.	5213.	5213.542	304.954	199.980	-176.727	9031.1	292.478	0.35
200.	390.	250.	47421.	13900.	13905.	6950.	6951.737	389.925	249.969	-223.963	12042.4	371.501	0.35
250.	635.	370.	59276.	17375.	17386.	8688.	8690.714	634.798	369.931	-351.655	15056.7	589.526	0.35
300.	1340.	315.	71131.	20850.	20878.	10425.	10428.284	1339.103	314.950	-578.918	18080.8	1108.221	0.35
350.	3260.	480.	82987.	24325.	24404.	12163.	12168.338	3254.697	479.885	-1307.104	21134.8	2654.260	0.35
400.	5720.	850.	94842.	27800.	27959.	13900.	13911.815	5703.704	849.638	-2293.670	24213.3	4652.366	0.35
450.	11660.	1120.	106697.	31275.	31640.	15638.	15655.014	11592.546	1119.372	-4449.172	27401.3	9404.878	0.35

TEST NUMBER 2 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	255.	80.	11855.	3475.	3476.	1738.	1737.639	254.967	79.997	-117.238	3010.2	215.021	0.35
100.	505.	150.	23710.	6950.	6954.	3475.	3475.521	504.873	149.989	-229.202	6021.9	423.896	0.35
150.	715.	220.	35566.	10425.	10432.	5213.	5213.647	714.745	219.977	-327.153	9034.8	601.793	0.35
200.	910.	270.	47421.	13900.	13913.	6950.	6951.876	909.587	269.963	-412.843	12048.7	763.641	0.35
250.	1335.	335.	59276.	17375.	17398.	8688.	8690.410	1334.110	334.944	-584.169	15067.3	1107.841	0.35
300.	2000.	390.	71131.	20850.	20892.	10425.	10429.066	1998.003	389.925	-835.775	18092.8	1641.040	0.35
350.	3510.	445.	82987.	24325.	24410.	12163.	12167.912	3503.854	444.902	-1382.065	21140.0	2850.622	0.35
400.	4445.	485.	94842.	27800.	27924.	13900.	13906.741	4435.150	484.882	-1722.011	24182.6	3602.025	0.35
450.	4290.	510.	106697.	31275.	31409.	15638.	15645.475	4280.824	509.870	-1676.743	27201.2	3479.909	0.35
500.	3060.	470.	118552.	34750.	34856.	17375.	17383.166	3055.328	469.889	-1233.826	30186.5	2493.724	0.35
550.	2940.	450.	130407.	38225.	38337.	19113.	19121.101	2935.686	449.899	-1184.955	33201.2	2395.902	0.35

TABLE G-25. STRESS-STRAIN DATA ON CYLINDER NO. CY-4 (1:0)

TEST NUMBFR 3 GAGES 7 AND 8

HYDRO PRFSS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFFCTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICHOIN/IN
50.	-175.	100.	3475.	3475.	3475.	99.995	-174.984	183.319
100.	-300.	375.	6950.	6953.	6953.	374.930	-299.955	449.923
150.	-400.	625.	10425.	10432.	10432.	624.804	-399.919	683.149
200.	-500.	900.	13900.	13913.	13913.	899.596	-499.874	932.980
250.	-650.	1075.	17375.	17394.	17394.	1074.422	-649.789	1149.474
300.	-725.	1475.	20850.	20881.	20881.	1473.914	-724.737	1465.767
350.	-800.	1825.	24325.	24369.	24369.	1823.336	-799.681	1748.678
400.	-925.	2075.	27800.	27858.	27858.	2072.850	-924.573	1998.282
450.	-1025.	2475.	31275.	31352.	31352.	2471.943	-1024.476	2330.946
500.	-1125.	2975.	34750.	34853.	34853.	2970.583	-1124.368	2729.968
550.	-1275.	3475.	38225.	38358.	38358.	3468.975	-1274.187	3162.108

TEST NUMBER 3 GAGES 5 AND 6

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STHESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	-50.	350.	3475.	3476.	3476.	349.939	-50.000	266.626
100.	-125.	725.	6950.	6955.	6955.	724.737	-124.992	566.486
150.	-225.	1050.	10425.	10436.	10436.	1049.448	-224.975	849.615
200.	-250.	1425.	13900.	13920.	13920.	1423.986	-249.969	1115.970
250.	-350.	1975.	17375.	17409.	17409.	1973.052	-349.939	1548.661
300.	-400.	2650.	20850.	20905.	20905.	2646.495	-399.919	2030.943
350.	-425.	3850.	24325.	24419.	24419.	3842.608	-424.909	2845.011
400.	-425.	6300.	27800.	27975.	27975.	6280.238	-424.909	4470.099

TEST NUMBER 3 GAGES 3 AND 4

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	-50.	150.	3475.	3476.	3476.	149.989	-50.000	133.326
100.	-200.	325.	6950.	6952.	6952.	324.947	-199.980	349.951
150.	-275.	400.	10425.	10429.	10429.	399.919	-274.963	449.922
200.	-325.	400.	13900.	13906.	13906.	399.919	-324.947	483.244
250.	-525.	350.	17375.	17381.	17381.	349.939	-524.862	583.201
300.	-675.	525.	20850.	20861.	20861.	524.862	-674.773	799.756
350.	-850.	1125.	24325.	24352.	24352.	1124.368	-849.638	1316.004
400.	-950.	2175.	27800.	27860.	27860.	2172.638	-949.548	2081.457
450.	-1225.	3725.	31275.	31391.	31391.	3718.079	-1224.251	3294.886
500.	-1350.	5700.	34750.	34948.	34948.	5683.816	-1349.090	4688.604
550.	-1700.	9525.	38225.	38589.	38589.	9479.922	-1698.557	7452.320

TEST NUMBER 3 GAGES 1 AND 2

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	0.	400.	3475.	3476.	3476.	399.919	0.000	266.613
100.	-100.	775.	6950.	6955.	6955.	774.700	-99.995	583.130
150.	-200.	1100.	10425.	10436.	10436.	1099.395	-199.980	866.250
200.	-275.	1475.	13900.	13921.	13921.	1473.914	-274.963	1165.918
250.	-425.	2050.	17375.	17411.	17411.	2047.901	-424.909	1648.540
300.	-500.	3000.	20850.	20913.	20913.	2995.509	-499.874	2330.256
350.	-600.	4900.	24325.	24444.	24444.	4888.033	-599.821	3658.569
400.	-600.	7925.	27800.	28020.	28020.	7893.762	-599.821	5662.389

TABLE G-26. STRESS-STRAIN DATA ON CYLINDER NO. CY-5 (1:1)

TEST NUMBER 4 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	150.	150.	23710.	3475.	3476.	3475.	3475.521	149.989	149.989	-104.993	3475.5	169.988	0.35
100.	225.	450.	47421.	6950.	6952.	6950.	6953.127	224.975	449.899	-236.206	6952.3	403.875	0.35
150.	650.	675.	71131.	10425.	10432.	10425.	10432.037	649.789	674.773	-463.596	10431.9	750.723	0.35
200.	850.	820.	94842.	13900.	13912.	13900.	13911.398	849.638	819.664	-584.256	13911.6	946.096	0.35
250.	1125.	1075.	118552.	17375.	17395.	17375.	17393.678	1124.368	1074.422	-769.577	17394.1	1246.315	0.35
300.	1425.	1300.	142263.	20850.	20880.	20850.	20877.105	1423.986	1299.155	-953.099	20878.4	1544.795	0.35
350.	1675.	1525.	165973.	24325.	24366.	24325.	24362.096	1673.599	1523.838	-1119.103	24363.9	1813.943	0.35
400.	1975.	1675.	189683.	27800.	27855.	27800.	27846.565	1973.052	1673.599	-1276.328	27850.7	2073.656	0.35
450.	2275.	2000.	213394.	31275.	31346.	31275.	31337.550	2272.415	1998.003	-1494.646	31341.9	2425.085	0.35
500.	2625.	2250.	237104.	34750.	34841.	34750.	34828.187	2621.560	2247.473	-1704.162	34834.7	2767.559	0.35
550.	2950.	2500.	260815.	38225.	38338.	38225.	38320.563	2945.657	2496.880	-1904.888	38329.2	3094.969	0.35

TEST NUMBER 4 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	275.	250.	23710.	3475.	3476.	3475.	3475.869	274.963	249.969	-183.726	3475.9	297.812	0.35
100.	525.	525.	47421.	6950.	6954.	6950.	6953.649	524.862	524.862	-367.403	6953.6	594.843	0.35
150.	875.	750.	71131.	10425.	10434.	10425.	10432.819	874.617	749.719	-568.518	10433.5	923.277	0.35
200.	1250.	925.	94842.	13900.	13917.	13900.	13912.858	1249.220	924.573	-760.828	13915.1	1245.995	0.35
250.	1725.	1150.	118552.	17375.	17405.	17375.	17394.981	1723.513	1149.340	-1005.499	17400.0	1661.359	0.35
300.	2525.	1325.	142263.	20850.	20903.	20850.	20877.626	2521.817	1324.123	-1346.079	20890.1	2286.437	0.35
350.	3975.	1550.	165973.	24325.	24422.	24325.	24362.704	3967.121	1548.800	-1930.572	24392.3	3423.354	0.35
400.	6475.	1800.	189683.	27800.	27980.	27800.	27850.040	6454.127	1798.383	-2888.378	27915.2	5393.908	0.35

TEST NUMBER 4 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	50.	275.	23710.	3475.	3475.	3475.	3475.956	50.000	274.963	-113.737	3475.6	225.342	0.35
100.	75.	600.	47421.	6950.	6951.	6950.	6954.170	74.997	599.821	-236.186	6952.3	487.894	0.35
150.	100.	875.	71131.	10425.	10426.	10425.	10434.122	99.995	874.617	-341.114	10430.1	710.652	0.35
200.	175.	1150.	94842.	13900.	13902.	13900.	13915.985	174.984	1149.340	-463.513	13909.2	937.887	0.35
250.	250.	1425.	118552.	17375.	17379.	17375.	17399.759	249.969	1423.986	-585.884	17389.6	1165.861	0.35
300.	350.	1650.	142263.	20850.	20857.	20850.	20884.403	349.939	1648.640	-699.503	20870.9	1358.245	0.35
350.	675.	1850.	165973.	24325.	24341.	24325.	24370.001	674.773	1848.290	-883.072	24355.7	1582.148	0.35
400.	1275.	2000.	189683.	27800.	27835.	27800.	27855.600	1274.187	1998.003	-1145.267	27845.5	1900.749	0.35
450.	2150.	2075.	213394.	31275.	31342.	31275.	31339.896	2147.691	2072.850	-1477.189	31341.1	2392.030	0.35
500.	3450.	2200.	237104.	34750.	34870.	34750.	34826.450	3444.063	2197.583	-1974.576	34848.2	3276.932	0.35
550.	5275.	2100.	260815.	38225.	38427.	38225.	38305.273	5261.136	2097.798	-2575.627	38366.1	4552.471	0.35

TEST NUMBER 4 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	225.	225.	23710.	3475.	3476.	3475.	3475.782	224.975	224.975	-157.482	3475.8	254.971	0.35
100.	450.	575.	47421.	6950.	6953.	6950.	6953.996	449.899	574.835	-358.657	6953.6	585.146	0.35
150.	750.	800.	71131.	10425.	10433.	10425.	10433.340	749.719	799.681	-542.290	10433.1	878.467	0.35
200.	1075.	1000.	94842.	13900.	13915.	13900.	13913.900	1074.422	999.500	-725.873	13914.4	1176.019	0.35
250.	1475.	1225.	118552.	17375.	17401.	17375.	17396.284	1473.914	1224.251	-944.358	17398.5	1535.739	0.35
300.	2050.	1475.	142263.	20850.	20893.	20850.	20880.754	2047.901	1473.914	-1232.635	20886.8	2023.022	0.35
350.	3175.	1700.	165973.	24325.	24402.	24325.	24366.353	3169.970	1698.557	-1703.985	24384.3	2886.666	0.35
400.	5250.	2000.	189683.	27800.	27946.	27800.	27855.600	5236.266	1998.003	-2531.994	27900.9	4505.628	0.35

TABLE G-27. STRESS-STRAIN DATA ON CYLINDER NO. CY-2 (2:1)

TEST NUMBER 5 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	250.	25.	11855.	3475.	3476.	1738.	1737.543	249.969	25.000	-96.239	3010.2	202.852	0.35
100.	550.	100.	23710.	6950.	6954.	3475.	3475.348	549.849	99.995	-227.445	6022.2	450.622	0.35
150.	825.	175.	35566.	10425.	10434.	5213.	5213.412	824.661	174.984	-349.876	9035.8	679.394	0.35
200.	1125.	250.	47421.	13900.	13916.	6950.	6951.737	1124.368	249.969	-481.018	12051.3	928.102	0.35
250.	1475.	300.	59276.	17375.	17401.	8688.	8690.106	1473.914	299.955	-620.854	15069.4	1212.355	0.35
300.	1775.	375.	71131.	20850.	20887.	10425.	10428.909	1773.427	374.930	-751.925	18088.7	1460.821	0.35
350.	2100.	450.	82987.	24325.	24376.	12163.	12167.973	2097.798	449.899	-891.694	21110.3	1729.001	0.35
400.	2475.	500.	94842.	27800.	27869.	13900.	13906.950	2471.943	499.874	-1040.136	24135.1	2032.808	0.35
450.	2825.	575.	106697.	31275.	31363.	15638.	15646.492	2821.017	574.835	-1188.548	27161.5	2320.510	0.35
500.	3225.	650.	118552.	34750.	34862.	17375.	17386.294	3219.811	649.789	-1354.360	30191.5	2647.627	0.35
550.	3650.	700.	130407.	38225.	38365.	19113.	19125.879	3643.355	699.756	-1520.089	33224.7	2990.862	0.35

TEST NUMBER 5 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	200.	50.	11855.	3475.	3476.	1738.	1737.587	199.980	50.000	-87.493	3010.0	166.024	0.35
100.	400.	125.	23710.	6950.	6953.	3475.	3475.434	399.919	124.992	-183.719	6021.3	337.152	0.35
150.	600.	200.	35566.	10425.	10431.	5213.	5213.542	599.821	199.980	-279.930	9033.7	508.625	0.35
200.	900.	350.	47421.	13900.	13913.	6950.	6952.432	899.596	349.939	-437.337	12048.6	775.932	0.35
250.	1300.	475.	59276.	17375.	17398.	8688.	8691.627	1299.155	474.888	-620.915	15066.8	1112.242	0.35
300.	1800.	500.	71131.	20850.	20888.	10425.	10430.212	1798.383	499.874	-804.390	18089.1	1502.713	0.35
350.	2675.	625.	82987.	24325.	24390.	12163.	12170.102	2671.429	624.804	-1153.682	21122.4	2210.237	0.35
400.	4500.	675.	94842.	27800.	27925.	13900.	13909.383	4489.905	674.773	-1807.637	24183.9	3662.926	0.35
450.	8600.	775.	106697.	31275.	31544.	15638.	15649.619	8563.231	774.700	-3268.276	27318.1	6944.085	0.35

TEST NUMBER 5 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AX AL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	75.	75.	11855.	3475.	3475.	1738.	1737.630	74.997	74.997	-52.498	3009.7	84.996	0.35
100.	125.	100.	23710.	6950.	6951.	3475.	3475.348	124.992	99.995	-78.746	6019.6	128.307	0.35
150.	150.	175.	35566.	10425.	10427.	5213.	5213.412	149.989	174.984	-113.741	9029.7	184.716	0.35
200.	250.	375.	47421.	13900.	13903.	6950.	6952.606	249.969	374.930	-218.715	12040.8	361.385	0.35
250.	650.	525.	59276.	17375.	17386.	8688.	8692.061	649.789	524.862	-411.128	15057.0	669.532	0.35
300.	1900.	750.	71131.	20850.	20890.	10425.	10432.819	1898.198	749.719	-926.771	18090.9	1640.465	0.35
350.	4650.	1000.	82987.	24325.	24438.	12163.	12174.663	4639.223	999.500	-1973.553	21164.1	3824.350	0.35
400.	8625.	1050.	94842.	27800.	28040.	13900.	13914.595	8588.018	1049.448	-3373.113	24283.4	6983.436	0.35

TEST NUMBER 5 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	125.	75.	11855.	3475.	3475.	1738.	1737.630	124.992	74.997	-69.996	3009.8	116.945	0.35
100.	275.	125.	23710.	6950.	6952.	3475.	3475.434	274.963	124.992	-139.984	6020.5	242.618	0.35
150.	450.	225.	35566.	10425.	10430.	5213.	5213.673	449.899	224.975	-236.206	9032.4	403.875	0.35
200.	725.	375.	47421.	13900.	13910.	6950.	6952.606	724.737	374.930	-384.883	12046.5	655.055	0.35
250.	1050.	500.	59276.	17375.	17393.	8688.	8691.844	1049.448	499.874	-542.263	15063.0	933.527	0.35
300.	1500.	650.	71131.	20850.	20881.	10425.	10431.776	1498.875	649.789	-752.032	18083.7	1312.558	0.35
350.	2200.	800.	82987.	24325.	24379.	12163.	12172.230	2197.583	799.681	-1049.042	21112.4	1880.454	0.35
400.	3475.	900.	94842.	27800.	27897.	13900.	13912.510	3468.975	899.596	-1529.000	24159.2	2885.964	0.35
450.	6850.	1050.	106697.	31275.	31489.	15638.	15653.919	6826.646	1049.448	-2756.633	27270.6	5571.784	0.35

TABLE G-28. STRESS-STRAIN DATA ON CYLINDER NO. CY-10 (2:1)

TEST NUMBER 6 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	325.	75.	11855.	3475.	3476.	1738.	1737.630	324.947	74.997	-139.980	3010.4	268.679	0.35
100.	675.	100.	23710.	6950.	6955.	3475.	3475.348	674.773	99.995	-271.169	6022.9	550.341	0.35
150.	975.	200.	35566.	10425.	10435.	5213.	5213.542	974.525	199.980	-411.077	9037.1	801.831	0.35
200.	1275.	250.	47421.	13900.	13918.	6950.	6951.737	1274.187	249.969	-533.455	12053.1	1046.724	0.35
250.	1600.	300.	59276.	17375.	17403.	8688.	8690.106	1598.720	299.955	-664.536	15071.3	1311.434	0.35
300.	1950.	375.	71131.	20850.	20891.	10425.	10428.909	1948.101	374.930	-813.061	18091.8	1599.319	0.35
350.	2300.	425.	82987.	24325.	24381.	12163.	12167.669	2297.359	424.909	-952.794	21114.5	1883.709	0.35
400.	2675.	500.	94842.	27800.	27874.	13900.	13906.950	2671.429	499.874	-1109.956	24139.9	2191.198	0.35
450.	3050.	575.	106697.	31275.	31370.	15638.	15646.492	3045.358	574.835	-1267.067	27167.6	2498.582	0.35
500.	3425.	625.	118552.	34750.	34869.	17375.	17385.859	3419.148	624.804	-1415.383	30197.5	2802.515	0.35
550.	3800.	675.	130407.	38225.	38370.	19113.	19125.401	3792.797	674.773	-1563.649	33229.7	3106.414	0.35

TEST NUMBER 6 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	275.	100.	11855.	3475.	3476.	1738.	1737.674	274.963	99.995	-131.235	3010.3	235.267	0.35
100.	425.	200.	23710.	6950.	6953.	3475.	3475.695	424.909	199.980	-218.711	6021.4	377.166	0.35
150.	675.	250.	35566.	10425.	10432.	5213.	5213.803	674.773	249.969	-323.660	9034.4	578.576	0.35
200.	975.	300.	47421.	13900.	13914.	6950.	6952.085	974.525	299.955	-446.068	12049.5	820.525	0.35
250.	1375.	375.	59276.	17375.	17399.	8688.	8690.758	1374.056	374.930	-612.145	15067.9	1146.741	0.35
300.	2125.	450.	71131.	20850.	20894.	10425.	10429.691	2122.746	449.899	-900.426	18095.0	1748.737	0.35
350.	3575.	525.	82987.	24325.	24412.	12163.	12168.885	3568.626	524.862	-1432.721	21141.4	2910.139	0.35
400.	6200.	625.	94842.	27800.	27972.	13900.	13908.687	6180.860	624.804	-2381.982	24224.9	5016.258	0.35

TEST NUMBER 6 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	25.	100.	11855.	3475.	3475.	1738.	1737.674	25.000	99.995	-43.748	3009.5	83.016	0.35
100.	25.	125.	23710.	6950.	6950.	3475.	3475.434	25.000	124.992	-52.497	6019.0	102.748	0.35
150.	25.	175.	35566.	10425.	10425.	5213.	5213.412	25.000	174.984	-69.994	9028.5	142.621	0.35
200.	50.	250.	47421.	13900.	13901.	6950.	6951.737	50.000	249.969	-104.989	12038.4	205.483	0.35
250.	50.	275.	59276.	17375.	17376.	8688.	8689.889	50.000	274.963	-113.737	15047.9	225.342	0.35
300.	100.	275.	71131.	20850.	20852.	10425.	10427.867	99.995	274.963	-131.235	18058.4	235.267	0.35
350.	225.	250.	82987.	24325.	24330.	12163.	12165.541	224.975	249.969	-166.230	21070.8	269.522	0.35
400.	350.	175.	94842.	27800.	27810.	13900.	13902.432	349.939	174.984	-183.723	24083.9	314.139	0.35
450.	475.	25.	106697.	31275.	31290.	15638.	15637.891	474.888	25.000	-174.961	27097.8	384.328	0.35
500.	500.	-250.	118552.	34750.	34767.	17375.	-17379.344	499.874	-249.969	-87.467	45989.6	455.495	0.35
550.	675.	900.	130407.	38225.	38251.	19113.	19129.701	674.773	899.596	-551.029	33126.2	901.535	0.35

TEST NUMBER 6 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	300.	100.	11855.	3475.	3476.	1738.	1737.674	299.955	99.995	-139.982	3010.3	254.348	0.35
100.	475.	125.	23710.	6950.	6953.	3475.	3475.434	474.888	124.992	-209.958	6021.7	395.427	0.35
150.	700.	250.	35566.	10425.	10432.	5213.	5213.803	699.756	249.969	-332.404	9034.6	597.554	0.35
200.	925.	325.	47421.	13900.	13913.	6950.	6952.259	924.573	324.947	-437.332	12048.9	788.163	0.35
250.	1275.	450.	59276.	17375.	17397.	8688.	8691.409	1274.187	449.899	-603.430	15066.4	1086.728	0.35
300.	1950.	550.	71131.	20850.	20891.	10425.	10430.734	1948.101	549.849	-874.282	18091.8	1629.526	0.35
350.	3175.	700.	82987.	24325.	24402.	12163.	12171.014	3169.970	699.756	-1354.404	21133.0	2615.828	0.35
400.	5275.	925.	94842.	27800.	27947.	13900.	13912.858	5261.136	924.573	-2164.998	24202.6	4307.582	0.35

TABLE G-29. STRESS-STRAIN DATA ON CYLINDER NO. CY-11 (1:1)

TEST NUMRER 7 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	250.	225.	23710.	3475.	3476.	3475.	3475.782	249.969	224.975	-166.230	3475.8	269.522	0.35
100.	475.	450.	47421.	6950.	6953.	6950.	6953.127	474.888	449.899	-323.675	6953.2	524.244	0.35
150.	700.	675.	71131.	10425.	10432.	10425.	10432.037	699.756	674.773	-481.085	10432.2	779.033	0.35
200.	1000.	950.	94842.	13900.	13914.	13900.	13913.205	999.500	949.548	-682.167	13913.6	1104.837	0.35
250.	1225.	1150.	118552.	17375.	17396.	17375.	17394.981	1224.251	1149.340	-830.757	17395.6	1345.730	0.35
300.	1500.	1400.	142263.	20850.	20881.	20850.	20879.190	1498.875	1399.020	-1014.264	20880.2	1643.153	0.35
350.	1825.	1650.	165973.	24325.	24369.	24325.	24365.136	1823.336	1648.640	-1215.192	24367.3	1970.037	0.35
400.	2125.	1900.	189683.	27800.	27859.	27800.	27852.820	2122.746	1898.198	-1407.330	27855.9	2282.220	0.35
450.	2525.	2325.	213394.	31275.	31354.	31275.	31347.714	2521.817	2322.302	-1695.442	31350.8	2747.417	0.35
500.	2850.	2525.	237104.	34750.	34849.	34750.	34837.744	2845.946	2521.817	-1878.717	34843.4	3047.484	0.35

TEST NUMRER 7 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	425.	225.	23710.	3475.	3476.	3475.	3475.782	424.909	224.975	-227.459	3476.1	385.935	0.35
100.	700.	400.	47421.	6950.	6955.	6950.	6952.780	699.756	399.919	-384.886	6953.8	646.747	0.35
150.	1050.	550.	71131.	10425.	10436.	10425.	10430.734	1049.448	549.849	-559.754	10433.3	951.064	0.35
200.	1550.	750.	94842.	13900.	13922.	13900.	13910.425	1548.800	749.719	-804.482	13916.0	1381.787	0.35
250.	2025.	975.	118552.	17375.	17410.	17375.	17391.941	2022.953	974.525	-1049.117	17401.1	1803.204	0.35
300.	3075.	1125.	142263.	20850.	20914.	20850.	20873.456	3070.282	1124.368	-1468.127	20893.8	2629.101	0.35
350.	5325.	1300.	165973.	24325.	24455.	24325.	24356.623	5310.873	1299.155	-2313.510	24405.7	4403.949	0.35

TEST NUMBER 7 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	50.	250.	23710.	3475.	3475.	3475.	3475.869	50.000	249.969	-104.989	3475.5	205.483	0.35
100.	100.	425.	47421.	6950.	6951.	6950.	6952.954	99.995	424.909	-183.717	6951.8	351.659	0.35
150.	200.	600.	71131.	10425.	10427.	10425.	10431.255	199.980	599.821	-279.930	10429.2	508.625	0.35
200.	175.	725.	94842.	13900.	13902.	13900.	13910.077	174.984	724.737	-314.902	13906.3	600.567	0.35
250.	0.	900.	118552.	17375.	17375.	17375.	17390.638	0.000	899.596	-314.858	17382.8	727.752	0.35
300.	-100.	1050.	142263.	20850.	-20852.	20850.	20871.893	-99.995	1049.448	-332.309	36134.0	854.328	0.35
350.	-100.	1275.	165973.	24325.	-24327.	24325.	24356.014	-99.995	1274.187	-410.967	42161.1	1035.463	0.35
400.	700.	1575.	189683.	27800.	27819.	27800.	27843.785	699.756	1573.762	-795.731	27831.6	1383.623	0.35
450.	1725.	2100.	213394.	31275.	31329.	31275.	31340.677	1723.513	2097.798	-1337.459	31334.8	2176.165	0.35
500.	2100.	2400.	237104.	34750.	34823.	34750.	34833.400	2097.798	2397.124	-1573.223	34828.2	2552.979	0.35

TEST NUMRER 7 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	500.	75.	23710.	3475.	3477.	3475.	3475.261	499.874	74.997	-201.205	3476.0	407.791	0.35
100.	700.	125.	47421.	6950.	6955.	6950.	6950.869	699.756	124.992	-288.662	6952.9	573.185	0.35
150.	1050.	200.	71131.	10425.	10436.	10425.	10427.085	1049.448	199.980	-437.300	10431.5	861.284	0.35
200.	1475.	300.	94842.	13900.	13921.	13900.	13904.170	1473.914	299.955	-620.854	13912.3	1212.355	0.35
250.	1925.	375.	118552.	17375.	17408.	17375.	17381.516	1923.150	374.930	-804.328	17395.0	1579.506	0.35
300.	2825.	450.	142263.	20850.	20909.	20850.	20859.383	2821.017	449.899	-1144.820	20884.2	2304.256	0.35
350.	4650.	600.	165973.	24325.	24438.	24325.	24339.595	4639.223	599.821	-1833.665	24389.0	3775.267	0.35
400.	7700.	750.	189683.	27800.	28014.	27800.	27820.850	7670.506	749.719	-2947.079	27918.0	6223.552	0.35

TABLE G-30. STRESS-STRAIN DATA ON CYLINDER NO. CY-12 (1:1)

TEST NUMBER 8 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	300.	250.	23710.	3475.	3476.	3475.	3475.869	299.955	249.969	-192.473	3476.0	312.957	0.35
100.	450.	500.	47421.	6950.	6953.	6950.	6953.475	449.899	499.874	-332.421	6953.3	538.978	0.35
150.	700.	725.	71131.	10425.	10432.	10425.	10432.558	699.756	724.737	-498.572	10432.4	807.341	0.35
200.	950.	950.	94842.	13900.	13913.	13900.	13913.205	949.548	949.548	-664.684	13913.2	1076.155	0.35
250.	1200.	1150.	118552.	17375.	17396.	17375.	17394.981	1199.280	1149.340	-822.017	17395.4	1331.197	0.35
300.	1500.	1400.	142263.	20850.	20881.	20850.	20879.190	1498.875	1399.020	-1014.264	20880.2	1643.153	0.35
350.	1750.	1650.	165973.	24325.	24368.	24325.	24365.136	1748.470	1648.640	-1188.989	24366.4	1925.892	0.35
400.	2100.	1850.	189683.	27800.	27858.	27800.	27851.430	2097.798	1848.290	-1381.131	27854.9	2240.752	0.35
450.	2400.	2100.	213394.	31275.	31350.	31275.	31340.677	2397.124	2097.798	-1573.223	31345.4	2552.979	0.35
500.	2750.	2350.	237104.	34750.	34846.	34750.	34831.663	2746.226	2347.244	-1782.714	34838.6	2895.477	0.35

TEST NUMBER 8 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	375.	275.	23710.	3475.	3476.	3475.	3475.956	374.930	274.963	-227.463	3476.1	372.768	0.35
100.	575.	475.	47421.	6950.	6954.	6950.	6953.301	574.835	474.888	-367.403	6953.6	597.635	0.35
150.	1025.	675.	71131.	10425.	10436.	10425.	10432.037	1024.476	674.773	-594.737	10433.9	983.847	0.35
200.	1575.	875.	94842.	13900.	13922.	13900.	13912.163	1573.762	874.617	-856.933	13917.0	1444.941	0.35
250.	2350.	1100.	118552.	17375.	17416.	17375.	17394.112	2347.244	1099.395	-1206.324	17405.0	2081.736	0.35
300.	3800.	1375.	142263.	20850.	20929.	20850.	20878.669	3792.797	1374.056	-1808.399	20904.0	3243.857	0.35
350.	6350.	1575.	165973.	24325.	24479.	24325.	24363.312	6329.923	1573.762	-2766.290	24421.6	5253.532	0.35

TEST NUMBER 8 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	150.	275.	23710.	3475.	3476.	3475.	3475.956	149.989	274.963	-148.733	3475.7	251.384	0.35
100.	150.	550.	47421.	6950.	6951.	6950.	6953.823	149.989	549.849	-244.943	6952.4	458.876	0.35
150.	250.	875.	71131.	10425.	10428.	10425.	10434.122	249.969	874.617	-393.605	10430.9	732.236	0.35
200.	350.	1100.	94842.	13900.	13905.	13900.	13915.290	349.939	1099.395	-507.267	13910.1	928.302	0.35
250.	400.	1300.	118552.	17375.	17382.	17375.	17397.587	399.919	1299.155	-594.676	17389.8	1093.866	0.35
300.	500.	1575.	142263.	20850.	20860.	20850.	20882.839	499.874	1573.762	-725.773	20871.6	1328.600	0.35
350.	725.	1850.	165973.	24325.	24343.	24325.	24370.001	724.737	1848.290	-900.559	24356.3	1595.837	0.35
400.	1275.	2125.	189683.	27800.	27835.	27800.	27859.075	1274.187	2122.746	-1188.927	27847.3	1986.295	0.35
450.	2075.	2475.	213394.	31275.	31340.	31275.	31352.406	2072.850	2471.943	-1590.678	31346.2	2585.670	0.35
500.	3400.	2800.	237104.	34750.	34868.	34750.	34847.300	3394.233	2796.088	-2166.612	34857.7	3524.806	0.35

TEST NUMBER 8 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	325.	275.	23710.	3475.	3476.	3475.	3475.956	324.947	274.963	-209.969	3476.0	341.172	0.35
100.	500.	500.	47421.	6950.	6953.	6950.	6953.475	499.874	499.874	-349.912	6953.5	566.524	0.35
150.	800.	700.	71131.	10425.	10433.	10425.	10432.297	799.681	699.756	-524.803	10432.8	851.637	0.35
200.	1075.	900.	94842.	13900.	13915.	13900.	13912.510	1074.422	899.596	-690.906	13913.7	1123.155	0.35
250.	1500.	1150.	118552.	17375.	17401.	17375.	17394.981	1498.875	1149.340	-926.875	17398.0	1514.164	0.35
300.	2175.	1400.	142263.	20850.	20895.	20850.	20879.190	2172.638	1399.020	-1250.080	20887.3	2072.637	0.35
350.	3375.	1600.	165973.	24325.	24407.	24325.	24363.920	3369.317	1598.720	-1738.813	24385.5	2995.075	0.35
400.	6100.	1825.	189683.	27800.	27970.	27800.	27850.735	6081.471	1823.336	-2766.682	27910.3	5109.682	0.35

TABLE G-31. STRESS-STRAIN DATA ON CYLINDER NO. CY-13 (1:0)

TEST NUMBER 9 GAGES 7 AND 8

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	-200.	325.	3475.	3476.	3476.	324.947	-199.980	349.951
100.	-300.	725.	6950.	6955.	6955.	724.737	-299.955	683.127
150.	-375.	1125.	10425.	10437.	10437.	1124.368	-374.930	999.532
200.	-500.	1525.	13900.	13921.	13921.	1523.838	-499.874	1349.142
250.	-600.	1925.	17375.	17408.	17408.	1923.150	-599.821	1681.981
300.	-700.	2400.	20850.	20900.	20900.	2397.124	-699.756	2064.587
350.	-825.	2850.	24325.	24394.	24394.	2845.946	-824.661	2447.071
400.	-900.	3325.	27800.	27892.	27892.	3319.485	-899.596	2812.720
450.	-1025.	3825.	31275.	31395.	31395.	3817.703	-1024.476	3228.119
500.	-1150.	4350.	34750.	34901.	34901.	4340.565	-1149.340	3659.937
550.	-1200.	4950.	38225.	38414.	38414.	4937.789	-1199.280	4091.380

TEST NUMBER 9 GAGES 5 AND 6

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	-175.	250.	3475.	3476.	3476.	249.969	-174.984	283.302
100.	-225.	550.	6950.	6954.	6954.	549.849	-224.975	516.549
150.	-250.	875.	10425.	10434.	10434.	874.617	-249.969	749.724
200.	-375.	1200.	13900.	13917.	13917.	1199.280	-374.930	1049.474
250.	-425.	1600.	17375.	17403.	17403.	1598.720	-424.909	1349.087
300.	-500.	2125.	20850.	20894.	20894.	2122.746	-499.874	1748.413
350.	-575.	2850.	24325.	24394.	24394.	2845.946	-574.835	2280.521
400.	-600.	4725.	27800.	27931.	27931.	4713.872	-599.821	3542.462

TEST NUMBER 9 GAGES 3 AND 4

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	-150.	100.	3475.	3475.	3475.	99.995	-149.989	166.656
100.	-225.	225.	6950.	6952.	6952.	224.975	-224.975	299.966
150.	-325.	325.	10425.	10428.	10428.	324.947	-324.947	433.263
200.	-525.	475.	13900.	13907.	13907.	474.888	-524.862	666.500
250.	-600.	800.	17375.	17389.	17389.	799.681	-599.821	933.001
300.	-700.	1350.	20850.	20878.	20878.	1349.090	-699.756	1365.897
350.	-750.	2325.	24325.	24382.	24382.	2322.302	-749.719	2048.013
400.	-825.	3875.	27800.	27908.	27908.	3867.512	-824.661	3128.115
450.	-875.	6475.	31275.	31478.	31478.	6454.127	-874.617	4885.829

TEST NUMBER 9 GAGES 1 AND 2

HYDRO PRESS PSI	TRAVRS STRAIN MICROIN/IN	LONG STRAIN	MSD STRESS PSI	TRUE STRESS PSI	EFFECTIVE STRESS PSI	TRU LONG STRAIN MICRO IN/IN	TRU TRAVRS STRAIN MICROIN/IN	EFFECTIVE STRAIN MICROIN/IN
50.	-150.	300.	3475.	3476.	3476.	299.955	-149.989	299.963
100.	-225.	600.	6950.	6954.	6954.	599.821	-224.975	549.864
150.	-275.	900.	10425.	10434.	10434.	899.596	-274.963	783.039
200.	-375.	1175.	13900.	13916.	13916.	1174.310	-374.930	1032.827
250.	-400.	1550.	17375.	17402.	17402.	1548.800	-399.919	1299.146
300.	-500.	2025.	20850.	20892.	20892.	2022.953	-499.874	1681.885
350.	-575.	2700.	24325.	24391.	24391.	2696.361	-574.835	2180.797
400.	-500.	4825.	27800.	27934.	27934.	4813.397	-499.874	3542.181

TABLE G-32. STRESS-STRAIN DATA ON CYLINDER NO. CY-16 (1:0)

TEST NUMBER 10 GAGES 7 AND 8

HYDRO PRESS	TRAVRS STRAIN	LONG STRAIN	MSD STRESS	TRUE STRESS	EFFECTIVE STRESS	TRU LONG STRAIN	TRU TRAVRS STRAIN	EFFECTIVE STRAIN
PSI	MICROIN/IN		PSI	PSI	PSI	MICRO IN/IN	MICROIN/IN	MICROIN/IN
50.	-150.	225.	3475.	3476.	3476.	224.975	-149.989	249.976
100.	-275.	525.	6950.	6954.	6954.	524.862	-274.963	533.217
150.	-350.	900.	10425.	10434.	10434.	899.596	-349.939	833.023
200.	-475.	1200.	13900.	13917.	13917.	1199.280	-474.888	1116.112
250.	-550.	1550.	17375.	17402.	17402.	1548.800	-549.849	1399.099
300.	-700.	1900.	20850.	20890.	20890.	1898.198	-699.756	1731.969
350.	-775.	2300.	24325.	24381.	24381.	2297.359	-774.700	2048.039
400.	-900.	2675.	27800.	27874.	27874.	2671.429	-899.596	2380.683
450.	-975.	3100.	31275.	31372.	31372.	3095.205	-974.525	2713.153
500.	-1100.	3500.	34750.	34872.	34872.	3493.889	-1099.395	3062.190
550.	-1225.	4000.	38225.	38378.	38378.	3992.022	-1224.251	3477.515

TEST NUMBER 10 GAGES 5 AND 6

HYDRO PRESS	TRAVRS STRAIN	LONG STRAIN	MSD STRESS	TRUE STRESS	EFFECTIVE STRESS	TRU LONG STRAIN	TRU TRAVRS STRAIN	EFFECTIVE STRAIN
PSI	MICROIN/IN		PSI	PSI	PSI	MICRO IN/IN	MICROIN/IN	MICROIN/IN
50.	-125.	275.	3475.	3476.	3476.	274.963	-124.992	266.637
100.	-225.	525.	6950.	6954.	6954.	524.862	-224.975	499.891
150.	-325.	825.	10425.	10434.	10434.	824.661	-324.947	766.405
200.	-400.	1125.	13900.	13916.	13916.	1124.368	-399.919	1016.192
250.	-500.	1500.	17375.	17401.	17401.	1498.875	-499.874	1332.500
300.	-575.	2000.	20850.	20892.	20892.	1998.003	-574.835	1715.225
350.	-600.	2650.	24325.	24389.	24389.	2646.495	-599.821	2164.211
400.	-650.	4475.	27800.	27924.	27924.	4465.016	-649.789	3409.870
450.	-625.	9225.	31275.	31564.	31564.	9182.709	-624.804	6538.342

TEST NUMBER 10 GAGES 3 AND 4

HYDRO PRESS	TRAVRS STRAIN	LONG STRAIN	MSD STRESS	TRUE STRESS	EFFECTIVE STRESS	TRU LONG STRAIN	TRU TRAVRS STRAIN	EFFECTIVE STRAIN
PSI	MICROIN/IN		PSI	PSI	PSI	MICRO IN/IN	MICROIN/IN	MICROIN/IN
50.	-125.	175.	3475.	3476.	3476.	174.984	-124.992	199.984
100.	-225.	300.	6950.	6952.	6952.	299.955	-224.975	349.953
150.	-300.	425.	10425.	10429.	10429.	424.909	-299.955	483.243
200.	-325.	425.	13900.	13906.	13906.	424.909	-324.947	499.904
250.	-400.	450.	17375.	17383.	17383.	449.899	-399.919	566.546
300.	-525.	500.	20850.	20860.	20860.	499.874	-524.862	683.157
350.	-575.	1050.	24325.	24351.	24351.	1049.448	-574.835	1082.856
400.	-675.	1900.	27800.	27853.	27853.	1898.198	-674.773	1715.314
450.	-700.	2825.	31275.	31363.	31363.	2821.017	-699.756	2347.182
500.	-700.	3825.	34750.	34883.	34883.	3817.703	-699.756	3011.639
550.	-800.	5000.	38225.	38416.	38416.	4987.542	-799.681	3858.149

TEST NUMBER 10 GAGES 1 AND 2

HYDRO PRESS	TRAVRS STRAIN	LONG STRAIN	MSD STRESS	TRUE STRESS	EFFECTIVE STRESS	TRU LONG STRAIN	TRU TRAVRS STRAIN	EFFECTIVE STRAIN
PSI	MICROIN/IN		PSI	PSI	PSI	MICRO IN/IN	MICROIN/IN	MICROIN/IN
50.	-100.	300.	3475.	3476.	3476.	299.955	-99.995	266.633
100.	-175.	675.	6950.	6955.	6955.	674.773	-174.984	566.504
150.	-300.	800.	10425.	10433.	10433.	799.681	-299.955	733.090
200.	-350.	1175.	13900.	13916.	13916.	1174.310	-349.939	1016.166
250.	-425.	1775.	17375.	17406.	17406.	1773.427	-424.909	1465.557
300.	-525.	2300.	20850.	20898.	20898.	2297.359	-524.862	1881.480
350.	-575.	3125.	24325.	24401.	24401.	3120.128	-574.835	2463.309
400.	-625.	5100.	27800.	27942.	27942.	5087.040	-624.804	3807.896

TABLE G-33. STRESS-STRAIN DATA ON CYLINDER NO. CY-14 WITH REINFORCED WELD (2:1)

TEST NUMBER 11 GAGES 7 AND 8

HYDRO PRESS	CIRCUM STRAIN	LONG STRAIN	AXIAL LOAD	MSD CR STRESS	TRU CR STRESS	MSD LN STRESS	TRU LONG STRESS	TRU CIRCM STRAIN	TRU LONG STRAIN	TRU RAD STRAIN	EFFECTIVE STRESS	EFFECTIVE STRAIN	MU
PSI	MICROIN/IN		POUNDS	PSI	PSI	PSI	PSI	MICROIN/IN	MICROIN/IN	MICROIN/IN	PSI	MICIN/IN	
50.	175.	0.	11855.	3475.	3476.	1738.	1737.500	174.984	0.000	-61.244	3010.0	141.558	0.35
100.	450.	100.	23718.	6950.	6953.	3475.	3475.348	449.899	99.995	-192.463	6021.6	371.362	0.35
150.	700.	150.	35566.	10425.	10432.	5213.	5213.282	699.756	149.989	-297.411	9034.6	576.725	0.35
200.	1000.	225.	47421.	13900.	13914.	6950.	6951.564	999.500	224.975	-428.566	12049.8	825.480	0.35
250.	1275.	300.	59276.	17375.	17397.	8688.	8690.106	1274.187	299.955	-550.950	15066.4	1054.545	0.35
300.	1550.	350.	71131.	20850.	20882.	10425.	10428.649	1548.800	349.939	-664.559	18084.6	1279.360	0.35
350.	1875.	425.	82987.	24325.	24371.	12163.	12167.669	1873.244	424.909	-804.354	21105.6	1547.636	0.35
400.	2200.	500.	94842.	27800.	27861.	13900.	13906.950	2197.583	499.874	-944.110	24128.5	1815.828	0.35
450.	2525.	575.	106697.	31275.	31354.	15638.	15646.492	2521.817	574.835	-1083.828	27153.4	2083.938	0.35
500.	2900.	650.	118552.	34750.	34851.	17375.	17386.294	2895.804	649.789	-1240.957	30181.7	2391.294	0.35
550.	3250.	700.	130407.	38225.	38349.	19113.	19125.879	3244.729	699.756	-1380.570	33211.4	2674.905	0.35
600.	3700.	750.	142263.	41700.	41854.	20850.	20865.637	3693.171	749.719	-1555.011	36246.9	3037.510	0.35
650.	4225.	825.	154118.	45175.	45366.	22587.	22606.135	4216.100	824.661	-1764.266	39288.1	3463.113	0.35
700.	4800.	900.	165973.	48650.	48884.	24325.	24346.893	4788.516	899.596	-1990.839	42334.5	3928.188	0.35
750.	5625.	975.	177828.	52125.	52418.	26063.	26087.911	5609.239	974.525	-2304.317	45395.7	4591.193	0.35
800.	6800.	1050.	189683.	55600.	55978.	27800.	27829.190	6776.984	1049.448	-2739.251	48478.7	5532.081	0.35
850.	10375.	1125.	201539.	59075.	59688.	29537.	29570.730	10321.549	1124.368	-4006.071	51692.0	8382.392	0.35
900.	6575.	1275.	213394.	62550.	62961.	31275.	31314.876	6553.478	1274.187	-2739.683	54526.3	5381.964	0.35
0.	8025.	0.	0.	0.	0.	0.	0.000	7992.971	0.000	-2797.540	0.0	6466.133	0.35
948.	8025.	750.	224775.	65886.	66415.	32943.	32967.707	7992.971	749.719	-3059.941	57517.3	6483.227	0.35
0.	8150.	275.	0.	0.	0.	0.	0.000	8116.968	274.963	-2937.176	0.0	6566.057	0.35
990.	8075.	1075.	234733.	68805.	69361.	34402.	34439.483	8042.572	1074.422	-3190.948	60068.5	6547.951	0.35

TEST NUMBER 11 GAGES 5 AND 6

HYDRO PRESS	CIRCUM STRAIN	LONG STRAIN	AXIAL LOAD	MSD CR STRESS	TRU CR STRESS	MSD LN STRESS	TRU LONG STRESS	TRU CIRCM STRAIN	TRU LONG STRAIN	TRU RAD STRAIN	EFFECTIVE STRESS	EFFECTIVE STRAIN	MU
PSI	MICROIN/IN		POUNDS	PSI	PSI	PSI	PSI	MICROIN/IN	MICROIN/IN	MICROIN/IN	PSI	MICIN/IN	
50.	350.	50.	11855.	3475.	3476.	1738.	1737.587	349.939	50.000	-139.979	3010.5	285.219	0.35
100.	750.	100.	23710.	6950.	6955.	3475.	3475.348	749.719	99.995	-297.400	6023.4	610.377	0.35
150.	1175.	175.	35566.	10425.	10437.	5213.	5213.412	1174.310	174.984	-472.253	9038.9	957.860	0.35
200.	1600.	225.	47421.	13900.	13922.	6950.	6951.564	1598.720	224.975	-638.293	12057.0	1302.701	0.35
250.	2025.	300.	59276.	17375.	17410.	8688.	8690.106	2022.953	299.955	-813.018	15077.7	1649.927	0.35
300.	2475.	350.	71131.	20850.	20902.	10425.	10428.649	2471.943	349.939	-987.659	18101.3	2014.443	0.35
350.	2950.	425.	82987.	24325.	24397.	12163.	12167.669	2945.657	424.909	-1179.698	21128.2	2401.272	0.35
400.	3425.	475.	94842.	27800.	27895.	13900.	13906.603	3419.148	474.888	-1362.913	24158.0	2785.450	0.35
450.	3950.	525.	106697.	31275.	31399.	15638.	15645.710	3942.219	524.862	-1563.478	27192.0	3209.437	0.35
500.	4550.	550.	118552.	34750.	34908.	17375.	17384.556	4539.681	549.849	-1781.335	30231.4	3691.083	0.35
550.	5150.	725.	130407.	38225.	38422.	19113.	19126.357	5136.784	724.737	-2051.532	33274.4	4185.841	0.35
600.	6100.	825.	142263.	41700.	41954.	20850.	20867.201	6081.471	824.661	-2417.146	36333.7	4952.437	0.35
650.	7075.	925.	154118.	45175.	45495.	22587.	22608.393	7050.090	924.573	-2791.132	39399.7	5738.333	0.35
700.	8800.	1050.	165973.	48650.	49078.	24325.	24350.541	8761.505	1049.448	-3433.834	42503.3	7122.764	0.35
750.	10525.	1125.	177828.	52125.	52674.	26063.	26091.820	10469.997	1124.368	-4058.028	45617.3	8501.784	0.35
800.	12600.	1175.	189683.	55600.	56301.	27800.	27832.665	12521.279	1174.310	-4793.456	48758.7	10156.203	0.35
850.	15400.	1325.	201539.	59075.	59985.	29537.	29576.637	15282.623	1324.123	-5812.361	51950.0	12389.669	0.35
900.	17525.	625.	213394.	62550.	63646.	31275.	31294.547	17373.208	624.804	-6299.304	55121.8	14054.182	0.35
0.	7600.	0.	0.	0.	0.	0.	0.000	7571.265	0.000	-2649.943	0.0	6124.983	0.35
948.	17700.	75.	224775.	65886.	67052.	32943.	32945.471	17545.179	74.997	-6167.061	58071.8	14192.650	0.35
0.	7825.	150.	0.	0.	0.	0.	0.000	7794.544	149.989	-2780.587	0.0	6304.511	0.35
990.	17750.	3550.	234733.	68805.	70026.	34402.	34524.629	17594.309	3543.714	-7398.308	60646.5	14466.651	0.35

TABLE G-33. STRESS-STRAIN DATA ON CYLINDER NO. CY-14 WITH REINFORCED WELD (2:1) (Cont'd)

TEST NUMBER 11 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	100.	0.	11855.	3475.	3475.	1738.	1737.500	99.995	0.000	-34.998	3009.7	80.894	0.35
100.	175.	0.	23710.	6950.	6951.	3475.	3475.000	174.984	0.000	-61.244	6019.9	141.558	0.35
150.	300.	0.	35566.	10425.	10428.	5213.	5212.500	299.955	0.000	-104.984	9031.0	242.656	0.35
200.	475.	25.	47421.	13900.	13907.	6950.	6950.174	474.888	25.000	-174.961	12043.5	384.328	0.35
250.	600.	50.	59276.	17375.	17385.	8688.	8687.934	599.821	50.000	-227.437	15056.2	486.171	0.35
300.	725.	75.	71131.	20850.	20865.	10425.	10425.782	724.737	74.997	-279.907	18069.7	588.298	0.35
350.	900.	100.	82987.	24325.	24347.	12163.	12163.716	899.596	99.995	-349.857	21085.0	730.732	0.35
400.	1075.	150.	94842.	27800.	27830.	13900.	13902.085	1074.422	149.989	-428.544	24101.4	875.365	0.35
450.	1275.	175.	106697.	31275.	31315.	15638.	15640.237	1274.187	174.984	-507.210	27119.5	1037.841	0.35
500.	1425.	200.	118552.	34750.	34800.	17375.	17378.475	1423.986	199.980	-568.388	30137.3	1160.281	0.35
550.	1600.	225.	130407.	38225.	38286.	19113.	19116.800	1598.720	224.975	-638.293	33156.8	1302.701	0.35
600.	1825.	275.	142263.	41700.	41776.	20850.	20855.734	1823.336	274.963	-734.405	36179.2	1487.602	0.35
650.	2025.	300.	154118.	45175.	45266.	22587.	22594.276	2022.953	299.955	-813.018	39201.9	1649.927	0.35
700.	2225.	350.	165973.	48650.	48758.	24325.	24333.514	2222.529	349.939	-900.364	42225.9	1814.896	0.35
750.	2475.	400.	177828.	52125.	52254.	26063.	26072.925	2471.943	399.919	-1005.152	45253.3	2019.774	0.35
800.	2700.	425.	189683.	55600.	55750.	27800.	27811.815	2696.361	424.909	-1092.445	48281.1	2201.863	0.35
850.	2900.	575.	201539.	59075.	59246.	29537.	29554.484	2895.804	574.835	-1214.724	51308.9	2379.816	0.35
900.	3100.	700.	213394.	62550.	62744.	31275.	31296.893	3095.205	699.756	-1328.236	54337.9	2556.811	0.35
0.	-125.	0.	0.	0.	0.	0.	0.000	-124.992	0.000	43.747	0.0	101.116	0.35
948.	3275.	925.	224775.	65886.	66102.	32943.	32973.472	3269.648	924.573	-1467.978	57245.9	2735.315	0.35
0.	-275.	100.	0.	0.	0.	0.	0.000	-274.963	99.995	61.239	0.0	238.107	0.35
990.	3350.	1175.	234733.	68805.	69035.	34402.	34442.923	3344.402	1174.310	-1581.549	59786.5	2850.694	0.35

TEST NUMBER 11 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	425.	25.	11855.	3475.	3476.	1738.	1737.543	424.909	25.000	-157.468	3010.7	343.959	0.35
100.	950.	125.	23710.	6950.	6957.	3475.	3475.434	949.548	124.992	-376.089	6024.6	772.915	0.35
150.	1425.	175.	35566.	10425.	10440.	5213.	5213.412	1423.986	174.984	-559.639	9041.2	1158.010	0.35
200.	1925.	225.	47421.	13900.	13927.	6950.	6951.564	1923.150	224.975	-751.844	12060.9	1563.015	0.35
250.	2425.	275.	59276.	17375.	17417.	8688.	8689.889	2422.064	274.963	-943.960	15083.7	1967.849	0.35
300.	2925.	325.	71131.	20850.	20911.	10425.	10428.388	2920.730	324.947	-1135.987	18109.5	2372.498	0.35
350.	3400.	350.	82987.	24325.	24408.	12163.	12166.757	3394.233	349.939	-1310.460	21137.7	2755.148	0.35
400.	3925.	400.	94842.	27800.	27909.	13900.	13905.560	3917.317	399.919	-1511.033	24170.1	3179.476	0.35
450.	4500.	450.	106697.	31275.	31416.	15638.	15644.537	4489.905	449.899	-1728.931	27206.9	3643.651	0.35
500.	5150.	475.	118552.	34750.	34929.	17375.	17383.253	5136.784	474.888	-1964.085	30249.5	4166.112	0.35
550.	5950.	550.	130407.	38225.	38452.	19113.	19123.012	5932.369	549.849	-2268.776	33300.9	4811.443	0.35
600.	7100.	625.	142263.	41700.	41996.	20850.	20863.031	7074.913	624.804	-2694.901	36369.9	5736.309	0.35
650.	9075.	675.	154118.	45175.	45585.	22587.	22602.747	9034.070	674.773	-3398.095	39478.2	7318.543	0.35
700.	11975.	725.	165973.	48650.	49233.	24325.	24342.636	11903.867	724.737	-4420.011	42637.5	9636.855	0.35
750.	15400.	750.	177828.	52125.	52928.	26063.	26082.047	15282.623	749.719	-5611.320	45838.3	12366.846	0.35
800.	18800.	775.	189683.	55600.	56645.	27800.	27821.545	18625.464	774.700	-6790.057	49058.8	15068.909	0.35
850.	14000.	600.	201539.	59075.	59902.	29537.	29555.223	13902.905	599.821	-5075.954	51878.2	11248.542	0.35
0.	11900.	50.	0.	0.	0.	0.	0.000	11829.752	50.000	-4157.913	0.0	9569.332	0.35
948.	12150.	50.	224775.	65886.	66687.	32943.	32944.647	12076.782	50.000	-4244.374	57753.6	9769.172	0.35
0.	12275.	25.	0.	0.	0.	0.	0.000	12200.272	25.000	-4278.845	0.0	9869.387	0.35
990.	12650.	250.	234733.	68805.	69675.	34402.	34411.101	12570.657	249.969	-4487.219	60342.2	10167.611	0.35

TABLE G-34. STRESS-STRAIN DATA ON CYLINDER NO. CY-9 WITH REINFORCED WELD (2:1)

TEST NUMBER 12 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	275.	75.	11855.	3475.	3476.	1738.	1737.630	274.963	74.997	-122.486	3010.3	229.469	0.35
100.	650.	175.	23710.	6950.	6955.	3475.	3475.608	649.789	174.984	-288.670	6022.8	541.832	0.35
150.	1000.	275.	35566.	10425.	10435.	5213.	5213.933	999.500	274.963	-446.062	9037.3	834.597	0.35
200.	1250.	300.	47421.	13900.	13917.	6950.	6952.085	1249.220	299.955	-542.211	12052.8	1034.899	0.35
250.	1600.	425.	59276.	17375.	17403.	8688.	8691.192	1598.720	424.909	-708.270	15071.3	1332.011	0.35
300.	1900.	500.	71131.	20850.	20890.	10425.	10430.212	1898.198	499.874	-839.325	18090.9	1580.632	0.35
350.	2275.	550.	82987.	24325.	24380.	12163.	12169.189	2272.415	549.849	-987.792	21114.0	1883.291	0.35
400.	2675.	675.	94842.	27800.	27874.	13900.	13909.383	2671.429	674.773	-1171.171	24139.9	2219.095	0.35
450.	3100.	725.	106697.	31275.	31372.	15638.	15648.837	3095.205	724.737	-1336.980	27168.9	2560.992	0.35
500.	3575.	825.	118552.	34750.	34874.	17375.	17389.334	3568.626	824.661	-1537.650	30202.0	2950.853	0.35
550.	4000.	900.	130407.	38225.	38378.	19113.	19129.701	3992.022	899.596	-1712.066	33236.3	3297.154	0.35
600.	4575.	975.	142263.	41700.	41891.	20850.	20870.329	4564.566	974.525	-1938.682	36278.6	3761.424	0.35
650.	5225.	1025.	154118.	45175.	45411.	22587.	22610.652	5211.398	1024.476	-2182.556	39327.2	4281.379	0.35
700.	6050.	1125.	165973.	48650.	48944.	24325.	24352.366	6031.772	1124.368	-2504.649	42387.2	4946.893	0.35
750.	7150.	1250.	177828.	52125.	52498.	26063.	26095.078	7124.560	1249.220	-2930.823	45464.6	5832.916	0.35
800.	9050.	1325.	189683.	55600.	56103.	27800.	27836.835	9009.294	1324.123	-3616.696	48587.3	7346.794	0.35
850.	12200.	1425.	201539.	59075.	59796.	29537.	29579.591	12126.179	1423.986	-4742.558	51785.6	9855.822	0.35
900.	18650.	1550.	213394.	62550.	63717.	31275.	31323.476	18478.222	1548.800	-7009.458	55182.7	14977.546	0.35

TEST NUMBER 12 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	325.	50.	11855.	3475.	3476.	1738.	1737.587	324.947	50.000	-131.231	3010.4	265.221	0.35
100.	750.	100.	23710.	6950.	6955.	3475.	3475.348	749.719	99.995	-297.400	6023.4	610.377	0.35
150.	1175.	150.	35566.	10425.	10437.	5213.	5213.282	1174.310	149.989	-463.505	9038.9	955.457	0.35
200.	1575.	200.	47421.	13900.	13922.	6950.	6951.390	1573.762	199.980	-620.809	12056.7	1280.374	0.35
250.	2025.	275.	59276.	17375.	17410.	8688.	8689.889	2022.953	274.963	-804.271	15077.7	1647.450	0.35
300.	2375.	325.	71131.	20850.	20900.	10425.	10428.388	2372.183	324.947	-943.996	18099.5	1932.094	0.35
350.	2875.	400.	82987.	24325.	24395.	12163.	12167.365	2870.875	399.919	-1144.778	21126.7	2338.907	0.35
400.	3225.	450.	94842.	27800.	27890.	13900.	13906.255	3219.811	449.899	-1284.399	24153.2	2623.319	0.35
450.	3825.	500.	106697.	31275.	31395.	15638.	15645.319	3817.703	499.874	-1511.152	27188.6	3107.300	0.35
500.	4275.	575.	118552.	34750.	34899.	17375.	17384.991	4265.888	574.835	-1694.253	30223.1	3473.580	0.35
550.	4800.	625.	130407.	38225.	38408.	19113.	19124.445	4788.516	624.804	-1894.662	33262.8	3897.266	0.35
600.	5300.	675.	142263.	41700.	41921.	20850.	20864.074	5286.005	674.773	-2086.272	36304.8	4300.834	0.35
650.	6000.	750.	154118.	45175.	45446.	22587.	22604.441	5982.071	749.719	-2356.126	39357.6	4865.966	0.35
700.	6900.	825.	165973.	48650.	48986.	24325.	24345.068	6876.303	824.661	-2695.337	42423.1	5590.251	0.35
750.	8500.	925.	177828.	52125.	52568.	26063.	26086.608	8464.079	924.573	-3286.028	45525.7	6874.079	0.35
800.	11200.	1025.	189683.	55600.	56223.	27800.	27828.495	11137.744	1024.476	-4256.777	48691.1	9032.793	0.35
850.	13475.	1100.	201539.	59075.	59871.	29537.	29569.991	13385.020	1099.395	-5069.545	51851.1	10848.076	0.35
900.	17600.	1200.	213394.	62550.	63651.	31275.	31312.530	17446.913	1199.280	-6526.168	55125.7	14129.376	0.35

TABLE G-34. STRESS-STRAIN DATA ON CYLINDER NO. CY-9 WITH REINFORCED WELD (2:1) (Cont'd)

TEST NUMBER 12 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	100.	0.	11855.	3475.	3475.	1738.	1737.500	99.995	0.000	-34.998	3009.7	80.894	0.35
100.	275.	25.	23710.	6950.	6952.	3475.	3475.087	274.963	25.000	-104.987	6020.5	222.980	0.35
150.	400.	50.	35566.	10425.	10429.	5213.	5212.761	399.919	50.000	-157.472	9031.9	325.294	0.35
200.	525.	75.	47421.	13900.	13907.	6950.	6950.521	524.862	74.997	-209.950	12044.1	427.791	0.35
250.	675.	100.	59276.	17375.	17387.	8688.	8688.369	674.773	99.995	-271.169	15057.3	550.341	0.35
300.	775.	125.	71131.	20850.	20866.	10425.	10426.303	774.700	124.992	-314.892	18070.6	632.952	0.35
350.	875.	150.	82987.	24325.	24346.	12163.	12164.324	874.617	149.989	-358.612	21084.5	715.638	0.35
400.	1000.	175.	94842.	27800.	27828.	13900.	13902.432	999.500	174.984	-411.070	24099.6	818.263	0.35
450.	1100.	225.	106697.	31275.	31309.	15638.	15641.018	1099.395	224.975	-463.530	27114.7	904.481	0.35
500.	1175.	250.	118552.	34750.	34791.	17375.	17379.344	1174.310	249.969	-498.498	30129.7	967.573	0.35
550.	1275.	275.	130407.	38225.	38274.	19113.	19117.756	1274.187	274.963	-542.203	33146.0	1050.447	0.35
600.	1350.	300.	142263.	41700.	41756.	20850.	20856.255	1349.090	299.955	-577.166	36162.0	1113.601	0.35
650.	1400.	350.	154118.	45175.	45238.	22587.	22595.406	1399.020	349.939	-612.136	39177.5	1161.504	0.35
700.	1425.	375.	165973.	48650.	48719.	24325.	24334.122	1423.986	374.930	-629.621	42192.2	1185.743	0.35
750.	1425.	400.	177828.	52125.	52199.	26063.	26072.925	1423.986	399.919	-638.367	45205.9	1190.709	0.35
800.	1450.	450.	189683.	55600.	55681.	27800.	27812.510	1448.950	449.899	-664.597	48220.8	1220.864	0.35
850.	1425.	550.	201539.	59075.	59159.	29537.	29553.746	1423.986	549.849	-690.842	51233.4	1227.095	0.35
900.	1200.	700.	213394.	62550.	62625.	31275.	31296.893	1199.280	699.756	-664.663	54234.9	1114.096	0.35
950.	900.	1000.	225249.	66025.	66084.	33012.	33045.513	899.596	999.500	-664.684	57230.8	1077.699	0.35

TEST NUMBER 12 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	425.	25.	11855.	3475.	3476.	1738.	1737.543	424.909	25.000	-157.468	3010.7	343.959	0.35
100.	925.	100.	23710.	6950.	6956.	3475.	3475.348	924.573	99.995	-358.599	6024.4	750.817	0.35
150.	1475.	150.	35566.	10425.	10440.	5213.	5213.282	1473.914	149.989	-568.366	9041.6	1196.264	0.35
200.	1950.	200.	47421.	13900.	13927.	6950.	6951.390	1948.101	199.980	-751.828	12061.2	1581.243	0.35
250.	2325.	250.	59276.	17375.	17415.	8688.	8689.672	2322.302	249.969	-900.295	15082.2	1885.783	0.35
300.	2800.	300.	71131.	20850.	20908.	10425.	10428.127	2796.088	299.955	-1083.615	18107.2	2270.440	0.35
350.	3250.	350.	82987.	24325.	24404.	12163.	12166.757	3244.729	349.939	-1258.134	21134.6	2634.872	0.35
400.	3750.	400.	94842.	27800.	27904.	13900.	13905.560	3742.986	399.919	-1450.017	24165.8	3039.212	0.35
450.	4175.	425.	106697.	31275.	31406.	15638.	15644.146	4166.309	424.909	-1606.926	27198.1	3381.540	0.35
500.	4650.	500.	118552.	34750.	34912.	17375.	17383.688	4639.223	499.874	-1798.684	30234.4	3767.233	0.35
550.	5075.	525.	130407.	38225.	38419.	19113.	19122.534	5062.166	524.862	-1955.460	33271.9	4109.236	0.35
600.	5575.	550.	142263.	41700.	41932.	20850.	20861.467	5559.517	549.849	-2138.278	36314.7	4511.192	0.35
650.	6500.	625.	154118.	45175.	45469.	22587.	22601.617	6478.966	624.804	-2486.320	39377.2	5256.248	0.35
700.	7150.	650.	165973.	48650.	48998.	24325.	24340.811	7124.560	649.789	-2721.022	42433.7	5777.745	0.35
750.	7900.	700.	177828.	52125.	52537.	26063.	26080.744	7868.958	699.756	-2999.050	45498.6	6380.390	0.35
800.	9350.	725.	189683.	55600.	56120.	27800.	27820.155	9306.559	724.737	-3510.953	48601.8	7540.666	0.35
850.	11650.	750.	201539.	59075.	59763.	29537.	29559.653	11582.661	749.719	-4316.333	51757.5	9378.409	0.35
900.	18550.	800.	213394.	62550.	63710.	31275.	31300.020	18380.046	799.681	-6712.904	55177.5	14871.033	0.35

TABLE G-35. STRESS-STRAIN DATA ON CYLINDER NO. CY-15 WITH REINFORCED WELD (2:1)

TEST NUMBER 13 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	225.	50.	11855.	3475.	3476.	1738.	1737.587	224.975	50.000	-96.241	3010.1	185.701	0.35
100.	525.	100.	23710.	6950.	6954.	3475.	3475.348	524.862	99.995	-218.700	6022.0	430.752	0.35
150.	700.	150.	35566.	10425.	10432.	5213.	5213.282	699.756	149.989	-297.411	9034.6	576.725	0.35
200.	950.	200.	47421.	13900.	13913.	6950.	6951.390	949.548	199.980	-402.335	12049.2	782.052	0.35
250.	1200.	275.	59276.	17375.	17396.	8688.	8689.889	1199.280	274.963	-515.985	15065.3	991.306	0.35
300.	1475.	300.	71131.	20850.	20881.	10425.	10428.127	1473.914	299.955	-620.854	18083.3	1212.355	0.35
350.	1775.	350.	82987.	24325.	24368.	12163.	12166.757	1773.427	349.939	-743.178	21103.5	1457.130	0.35
400.	2075.	400.	94842.	27800.	27858.	13900.	13905.560	2072.850	399.919	-865.469	24125.5	1701.870	0.35
450.	2375.	475.	106697.	31275.	31349.	15638.	15644.928	2372.183	474.888	-996.475	27149.3	1950.071	0.35
500.	2675.	500.	118552.	34750.	34843.	17375.	17383.688	2671.429	499.874	-1109.956	30174.9	2191.198	0.35
550.	3100.	575.	130407.	38225.	38343.	19113.	19123.490	3095.205	574.835	-1284.514	33206.5	2538.214	0.35
600.	3525.	650.	142263.	41700.	41847.	20850.	20863.553	3518.802	649.789	-1459.007	36240.6	2885.089	0.35
650.	3975.	700.	154118.	45175.	45355.	22587.	22603.311	3967.121	699.756	-1633.407	39278.3	3248.426	0.35
700.	4500.	750.	165973.	48650.	48869.	24325.	24343.244	4489.905	749.719	-1833.868	42321.8	3671.331	0.35
750.	5225.	825.	177828.	52125.	52397.	26063.	26084.002	5211.398	824.661	-2112.621	45377.6	4256.037	0.35
800.	6375.	900.	189683.	55600.	55954.	27800.	27825.020	6354.765	899.596	-2539.026	48458.2	5178.643	0.35
850.	9100.	1000.	201539.	59075.	59613.	29537.	29567.038	9058.844	999.500	-3520.420	51626.6	7357.847	0.35
900.	15950.	1200.	213394.	62550.	63548.	31275.	31312.530	15824.135	1199.280	-5958.195	55035.8	12820.000	0.35

TEST NUMBER 13 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	550.	0.	11855.	3475.	3477.	1738.	1737.500	549.849	0.000	-192.447	3011.1	444.815	0.35
100.	1125.	100.	23710.	6950.	6958.	3475.	3475.348	1124.368	99.995	-428.527	6025.6	911.672	0.35
150.	1525.	125.	35566.	10425.	10441.	5213.	5213.152	1523.838	124.992	-577.091	9042.1	1235.007	0.35
200.	2100.	200.	47421.	13900.	13929.	6950.	6951.390	2097.798	199.980	-804.222	12063.0	1701.755	0.35
250.	2500.	225.	59276.	17375.	17418.	8688.	8689.455	2496.880	224.975	-952.649	15084.8	2024.714	0.35
300.	3000.	300.	71131.	20850.	20913.	10425.	10428.127	2995.509	299.955	-1153.412	18110.8	2430.905	0.35
350.	3475.	325.	82987.	24325.	24410.	12163.	12166.453	3468.975	324.947	-1327.873	21139.3	2813.716	0.35
400.	3975.	375.	94842.	27800.	27911.	13900.	13905.213	3967.121	374.930	-1519.718	24171.3	3217.968	0.35
450.	4475.	425.	106697.	31275.	31415.	15638.	15644.146	4465.016	424.909	-1711.474	27206.2	3622.020	0.35
500.	5050.	475.	118552.	34750.	34925.	17375.	17383.253	5037.291	474.888	-1929.263	30246.5	4085.974	0.35
550.	5775.	500.	130407.	38225.	38446.	19113.	19122.056	5758.389	499.874	-2190.392	33295.1	4668.396	0.35
600.	6900.	575.	142263.	41700.	41988.	20850.	20861.989	6876.303	574.835	-2607.898	36362.7	5573.516	0.35
650.	8575.	600.	154118.	45175.	45562.	22587.	22601.053	8538.443	599.821	-3198.392	39458.6	6915.385	0.35
700.	11200.	675.	165973.	48650.	49195.	24325.	24341.419	11137.744	674.773	-4134.381	42604.8	9016.522	0.35
750.	14550.	750.	177828.	52125.	52883.	26063.	26082.047	14445.165	749.719	-5318.209	45799.8	11690.223	0.35
800.	18150.	825.	189683.	55600.	56609.	27800.	27822.935	17987.255	824.661	-6584.170	49027.3	14554.116	0.35

TABLE G-35. STRESS-STRAIN DATA ON CYLINDER NO. CY-15 WITH REINFORCED WELD (2:1) (Cont'd)

TEST NUMBER 13 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	100.	0.	11855.	3475.	3475.	1738.	1737.500	99.995	0.000	-34.998	3009.7	80.894	0.35
100.	225.	0.	23710.	6950.	6952.	3475.	3475.000	224.975	0.000	-78.741	6020.2	182.000	0.35
150.	300.	25.	35566.	10425.	10428.	5213.	5212.630	299.955	25.000	-113.734	9031.0	243.121	0.35
200.	475.	50.	47421.	13900.	13907.	6950.	6950.347	474.888	50.000	-183.711	12043.5	385.545	0.35
250.	575.	75.	59276.	17375.	17385.	8688.	8688.152	574.835	74.997	-227.441	15055.8	467.845	0.35
300.	700.	100.	71131.	20850.	20865.	10425.	10426.042	699.756	99.995	-279.913	18069.3	570.340	0.35
350.	800.	125.	82987.	24325.	24344.	12163.	12164.020	799.681	124.992	-323.636	21082.9	652.910	0.35
400.	900.	150.	94842.	27800.	27825.	13900.	13902.085	899.596	149.989	-367.355	24097.2	735.560	0.35
450.	1025.	175.	106697.	31275.	31307.	15638.	15640.237	1024.476	174.984	-419.811	27112.7	838.170	0.35
500.	1100.	200.	118552.	34750.	34788.	17375.	17378.475	1099.395	199.980	-454.781	30127.5	901.003	0.35
550.	1175.	225.	130407.	38225.	38270.	19113.	19116.800	1174.310	224.975	-489.750	33142.7	963.923	0.35
600.	1225.	275.	142263.	41700.	41751.	20850.	20855.734	1224.251	274.963	-524.725	36157.5	1011.002	0.35
650.	1275.	300.	154118.	45175.	45233.	22587.	22594.276	1274.187	299.955	-550.950	39172.6	1054.545	0.35
700.	1300.	325.	165973.	48650.	48713.	24325.	24332.906	1299.155	324.947	-568.436	42186.9	1078.591	0.35
750.	1300.	375.	177828.	52125.	52193.	26063.	26072.273	1299.155	374.930	-585.930	45200.3	1088.423	0.35
800.	1325.	450.	189683.	55600.	55674.	27800.	27812.510	1324.123	449.899	-620.908	48214.8	1124.874	0.35
850.	1275.	525.	201539.	59075.	59150.	29537.	29553.007	1274.187	524.862	-629.667	51225.7	1107.458	0.35
900.	1025.	725.	213394.	62550.	62614.	31275.	31297.674	1024.476	724.737	-612.224	54225.4	1006.213	0.35
950.	775.	925.	225249.	66025.	66076.	33012.	33043.037	774.700	924.573	-594.746	57223.6	966.801	0.35
1000.	0.	1575.	237104.	69500.	69500.	34750.	34804.731	0.000	1573.762	-550.817	60188.8	1273.138	0.35

TEST NUMBER 13 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	525.	0.	11855.	3475.	3477.	1738.	1737.500	524.862	0.000	-183.702	3011.0	424.601	0.35
100.	1075.	75.	23710.	6950.	6957.	3475.	3475.261	1074.422	74.997	-402.297	6025.3	870.167	0.35
150.	1475.	100.	35566.	10425.	10440.	5213.	5213.021	1473.914	99.995	-550.868	9041.6	1193.596	0.35
200.	2025.	175.	47421.	13900.	13928.	6950.	6951.216	2022.953	174.984	-769.278	12062.1	1639.998	0.35
250.	2500.	225.	59276.	17375.	17418.	8688.	8689.455	2496.880	224.975	-952.649	15084.8	2024.714	0.35
300.	3025.	300.	71131.	20850.	20913.	10425.	10428.127	3020.435	299.955	-1162.136	18111.3	2450.969	0.35
350.	3575.	350.	82987.	24325.	24412.	12163.	12166.757	3568.626	349.939	-1371.498	21141.4	2895.518	0.35
400.	4075.	375.	94842.	27800.	27913.	13900.	13905.213	4066.720	374.930	-1554.578	24173.7	3298.191	0.35
450.	4625.	475.	106697.	31275.	31420.	15638.	15644.928	4614.338	474.888	-1781.229	27210.3	3745.468	0.35
500.	5275.	500.	118552.	34750.	34933.	17375.	17383.688	5261.136	499.874	-2016.353	30253.2	4267.783	0.35
550.	6025.	600.	130407.	38225.	38455.	19113.	19123.968	6006.922	599.821	-2312.360	33303.4	4874.605	0.35
600.	7275.	675.	142263.	41700.	42003.	20850.	20864.074	7248.665	674.773	-2773.203	36376.2	5879.199	0.35
650.	8975.	775.	154118.	45175.	45580.	22587.	22605.005	8934.963	774.700	-3398.382	39474.3	7243.632	0.35
700.	11650.	875.	165973.	48650.	49217.	24325.	24346.284	11582.661	874.617	-4360.047	42623.8	9383.601	0.35
750.	15500.	1000.	177828.	52125.	52933.	26063.	26088.563	15381.102	999.500	-5733.211	45842.8	12454.129	0.35
800.	19325.	1100.	189683.	55600.	56674.	27800.	27830.580	19140.643	1099.395	-7084.013	49084.1	15493.277	0.35

TABLE G-36. STRESS-STRAIN DATA ON CYLINDER NO. CY-7 WITH REINFORCED WELD (1:1)

TEST NUMBER 14 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRFSS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	225.	225.	23710.	3475.	3476.	3475.	3475.782	224.975	224.975	-157.482	3475.8	254.971	0.35
100.	475.	500.	47421.	6950.	6953.	6950.	6953.475	474.888	499.874	-341.167	6953.4	552.553	0.35
150.	700.	700.	71131.	10425.	10432.	10425.	10432.297	699.756	699.756	-489.829	10432.3	793.057	0.35
200.	825.	900.	94842.	13900.	13911.	13900.	13912.510	824.661	899.596	-603.490	13912.0	978.036	0.35
250.	1100.	1200.	118552.	17375.	17394.	17375.	17395.850	1099.395	1199.280	-804.537	17395.0	1303.859	0.35
300.	1350.	1400.	142263.	20850.	20878.	20850.	20879.190	1349.090	1399.020	-961.839	20878.7	1557.529	0.35
350.	1550.	1625.	165973.	24325.	24363.	24325.	24364.528	1548.800	1623.681	-1110.368	24363.6	1798.259	0.35
400.	1800.	1900.	189683.	27800.	27850.	27800.	27852.820	1798.383	1898.198	-1293.803	27851.4	2095.521	0.35
450.	2050.	2125.	213394.	31275.	31339.	31275.	31341.459	2047.901	2122.746	-1459.726	31340.3	2363.762	0.35
500.	2625.	2425.	237104.	34750.	34841.	34750.	34834.269	2621.560	2422.064	-1765.269	34837.7	2860.374	0.35
550.	2850.	2650.	260815.	38225.	38334.	38225.	38326.296	2845.946	2646.495	-1922.354	38330.1	3114.513	0.35
600.	3175.	2850.	284525.	41700.	41832.	41700.	41818.845	3169.970	2845.946	-2105.571	41825.6	3414.148	0.35

TEST NUMBER 14 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	425.	175.	23710.	3475.	3476.	3475.	3475.608	424.909	174.984	-209.963	3476.0	369.296	0.35
100.	900.	350.	47421.	6950.	6956.	6950.	6952.432	899.596	349.939	-437.337	6954.3	775.932	0.35
150.	1350.	500.	71131.	10425.	10439.	10425.	10430.212	1349.090	499.874	-647.137	10434.6	1156.789	0.35
200.	1625.	650.	94842.	13900.	13923.	13900.	13909.035	1623.681	649.789	-795.714	13915.8	1405.657	0.35
250.	2125.	850.	118552.	17375.	17412.	17375.	17389.769	2122.746	849.638	-1040.335	17400.9	1837.745	0.35
300.	2525.	925.	142263.	20850.	20903.	20850.	20869.286	2521.817	924.573	-1206.237	20886.0	2159.729	0.35
350.	3000.	1100.	165973.	24325.	24398.	24325.	24351.758	2995.509	1099.395	-1433.217	24374.9	2565.714	0.35
400.	3400.	1250.	189683.	27800.	27895.	27800.	27834.750	3394.233	1249.220	-1625.209	27864.7	2908.158	0.35
450.	3800.	1475.	213394.	31275.	31394.	31275.	31321.131	3792.797	1473.914	-1843.349	31357.6	3271.004	0.35
500.	4775.	1650.	237104.	34750.	34916.	34750.	34807.338	4763.636	1648.640	-2244.297	34861.8	4054.333	0.35
550.	5275.	1750.	260815.	38225.	38427.	38225.	38291.894	5261.136	1748.470	-2453.362	38359.4	4459.888	0.35
600.	6075.	1900.	284525.	41700.	41953.	41700.	41779.230	6056.622	1898.198	-2784.187	41866.6	5107.231	0.35

TABLE G-36. STRESS-STRAIN DATA ON CYLINDER NO. CY-7 WITH REINFORCED WELD (1:1) (Cont'd)

TEST NUMBER 14 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	100.	100.	23710.	3475.	3475.	3475.	3475.348	99.995	99.995	-69.996	3475.3	113.327	0.35
100.	225.	225.	47421.	6950.	6952.	6950.	6951.564	224.975	224.975	-157.482	6951.6	254.971	0.35
150.	350.	350.	71131.	10425.	10429.	10425.	10428.649	349.939	349.939	-244.957	10428.6	396.598	0.35
200.	425.	425.	94842.	13900.	13906.	13900.	13905.907	424.909	424.909	-297.437	13905.9	481.564	0.35
250.	550.	600.	118552.	17375.	17385.	17375.	17385.425	549.849	599.821	-402.384	17385.0	652.118	0.35
300.	675.	700.	142263.	20850.	20864.	20850.	20864.595	674.773	699.756	-481.085	20864.3	779.033	0.35
350.	800.	825.	165973.	24325.	24344.	24325.	24345.068	799.681	824.661	-568.520	24344.8	920.573	0.35
400.	875.	925.	189683.	27800.	27824.	27800.	27825.715	874.617	924.573	-629.717	27825.0	1019.949	0.35
450.	1050.	1050.	213394.	31275.	31308.	31275.	31307.839	1049.448	1049.448	-734.614	31307.8	1189.375	0.35
500.	1250.	1200.	237104.	34750.	34793.	34750.	34791.700	1249.220	1199.280	-856.975	34792.6	1387.783	0.35
550.	1325.	1300.	260815.	38225.	38276.	38225.	38274.693	1324.123	1299.155	-918.147	38275.2	1486.594	0.35
600.	1350.	1350.	284525.	41700.	41756.	41700.	41756.295	1349.090	1349.090	-944.363	41756.3	1528.969	0.35

TEST NUMBER 14 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN MICROIN/IN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	350.	175.	23710.	3475.	3476.	3475.	3475.608	349.939	174.984	-183.723	3475.9	314.139	0.35
100.	775.	350.	47421.	6950.	6955.	6950.	6952.432	774.700	349.939	-393.624	6953.9	682.851	0.35
150.	1150.	525.	71131.	10425.	10437.	10425.	10430.473	1149.340	524.862	-585.971	10433.7	1014.914	0.35
200.	1450.	675.	94842.	13900.	13920.	13900.	13909.383	1448.950	674.773	-743.303	13914.8	1283.767	0.35
250.	1850.	900.	118552.	17375.	17407.	17375.	17390.638	1848.290	899.596	-961.760	17398.9	1650.660	0.35
300.	2275.	1000.	142263.	20850.	20897.	20850.	20870.850	2272.415	999.500	-1145.171	20884.2	1994.427	0.35
350.	2575.	1150.	165973.	24325.	24388.	24325.	24352.974	2571.691	1149.340	-1302.361	24370.3	2262.850	0.35
400.	2950.	1325.	189683.	27800.	27882.	27800.	27836.835	2945.657	1324.123	-1494.423	27859.5	2594.348	0.35
450.	3350.	1525.	213394.	31275.	31380.	31275.	31322.694	3344.402	1523.838	-1703.884	31351.3	2952.131	0.35
500.	4050.	1725.	237104.	34750.	34891.	34750.	34809.944	4041.820	1723.513	-2017.867	34850.4	3530.574	0.35
550.	4525.	1875.	260815.	38225.	38398.	38225.	38296.672	4514.793	1873.244	-2235.813	38347.4	3928.042	0.35
600.	5025.	2025.	284525.	41700.	41910.	41700.	41784.442	5012.416	2022.953	-2462.379	41847.1	4344.285	0.35

TABLE G-37. STRESS-STRAIN DATA ON RETEST OF CYLINDER NO. CY-7 WITH REINFORCED WELD (1:1)

TEST NUMBER 14 GAGES 7 AND 8

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRFSS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	375.	300.	23710.	3475.	3476.	3475.	3476.042	374.930	299.955	-236.210	3476.2	384.877	0.35
100.	550.	500.	47421.	6950.	6954.	6950.	6953.475	549.849	499.874	-367.403	6953.6	595.542	0.35
150.	800.	800.	71131.	10425.	10433.	10425.	10433.340	799.681	799.681	-559.776	10433.3	906.305	0.35
200.	1025.	1025.	94842.	13900.	13914.	13900.	13914.248	1024.476	1024.476	-717.133	13914.2	1161.072	0.35
250.	1300.	1300.	118552.	17375.	17398.	17375.	17397.587	1299.155	1299.155	-909.409	17397.6	1472.376	0.35
300.	1525.	1525.	142263.	20850.	20882.	20850.	20881.796	1523.838	1523.838	-1066.687	20881.8	1727.016	0.35
350.	1800.	1725.	165973.	24325.	24369.	24325.	24366.961	1798.383	1723.513	-1232.664	24367.9	1996.209	0.35
400.	2100.	2000.	189683.	27800.	27858.	27800.	27855.600	2097.798	1998.003	-1433.530	27857.0	2321.669	0.35
450.	2350.	2250.	213394.	31275.	31348.	31275.	31345.369	2347.244	2247.473	-1608.151	31346.9	2604.310	0.35

TEST NUMBER 14 GAGES 5 AND 6

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN SIRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	725.	225.	23710.	3475.	3478.	3475.	3475.782	724.737	224.975	-332.399	3476.7	610.640	0.35
100.	1075.	375.	47421.	6950.	6957.	6950.	6952.606	1074.422	374.930	-507.273	6955.0	915.221	0.35
150.	1525.	525.	71131.	10425.	10441.	10425.	10430.473	1523.838	524.862	-717.045	10435.7	1296.306	0.35
200.	1975.	700.	94842.	13900.	13927.	13900.	13909.730	1973.052	699.756	-935.483	13918.6	1683.572	0.35
250.	2475.	875.	118552.	17375.	17418.	17375.	17390.203	2471.943	874.617	-1171.296	17404.1	2108.733	0.35
300.	2875.	975.	142263.	20850.	20910.	20850.	20870.329	2870.875	974.525	-1345.890	20890.2	2438.651	0.35
350.	3350.	1175.	165973.	24325.	24406.	24325.	24353.582	3344.402	1174.310	-1581.549	24380.1	2850.694	0.35
400.	3800.	1250.	189683.	27800.	27906.	27800.	27834.750	3792.797	1249.220	-1764.706	27870.3	3212.454	0.35
450.	4250.	1400.	213394.	31275.	31408.	31275.	31318.785	4240.993	1399.020	-1974.005	31363.4	3592.595	0.35

TABLE G-37. STRESS-STRAIN DATA ON RETEST OF CYLINDER NO. CY-7 WITH REINFORCED WELD (1:1) (Cont'd)

TEST NUMBER 14 GAGES 3 AND 4

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	225.	150.	23710.	3475.	3476.	3475.	3475.521	224.975	149.989	-131.237	3475.7	216.845	0.35
100.	275.	250.	47421.	6950.	6952.	6950.	6951.737	274.963	249.969	-183.726	6951.8	297.812	0.35
150.	400.	375.	71131.	10425.	10429.	10425.	10428.909	399.919	374.930	-271.197	10429.0	439.319	0.35
200.	500.	500.	94842.	13900.	13907.	13900.	13906.950	499.874	499.874	-349.912	13907.0	566.524	0.35
250.	625.	625.	118552.	17375.	17386.	17375.	17385.859	624.804	624.804	-437.363	17385.9	708.111	0.35
300.	700.	725.	142263.	20850.	20865.	20850.	20865.116	699.756	724.737	-498.572	20864.9	807.341	0.35
350.	850.	875.	165973.	24325.	24346.	24325.	24346.284	849.638	874.617	-603.490	24346.0	977.185	0.35
400.	900.	1000.	189683.	27800.	27825.	27800.	27827.800	899.596	999.500	-664.684	27826.4	1077.699	0.35
450.	1000.	1125.	213394.	31275.	31306.	31275.	31310.184	999.500	1124.368	-743.354	31308.2	1205.683	0.35
500.	0.	0.	237104.	34750.	34750.	34750.	34750.000	0.000	0.000	0.000	34750.0	0.000	0.35
550.	0.	0.	260815.	38225.	38225.	38225.	38225.000	0.000	0.000	0.000	38225.0	0.000	0.35

TEST NUMBER 14 GAGES 1 AND 2

HYDRO PRESS PSI	CIRCUM STRAIN MICROIN/IN	LONG STRAIN	AXIAL LOAD POUNDS	MSD CR STRESS PSI	TRU CR STRESS PSI	MSD LN STRESS PSI	TRU LONG STRESS PSI	TRU CIRCM STRAIN MICROIN/IN	TRU LONG STRAIN MICROIN/IN	TRU RAD STRAIN MICROIN/IN	EFFECTIVE STRESS PSI	EFFECTIVE STRAIN MICIN/IN	MU
50.	650.	250.	23710.	3475.	3477.	3475.	3475.869	649.789	249.969	-314.915	3476.6	559.683	0.35
100.	900.	400.	47421.	6950.	6956.	6950.	6952.780	899.596	399.919	-454.830	6954.5	790.884	0.35
150.	1300.	575.	71131.	10425.	10439.	10425.	10430.994	1299.155	574.835	-655.897	10434.8	1141.302	0.35
200.	1625.	725.	94842.	13900.	13923.	13900.	13910.077	1623.681	724.737	-821.946	13916.3	1428.396	0.35
250.	2150.	925.	118552.	17375.	17412.	17375.	17391.072	2147.691	924.573	-1075.293	17401.7	1878.717	0.35
300.	2500.	1075.	142263.	20850.	20902.	20850.	20872.414	2496.880	1074.422	-1249.956	20887.3	2184.027	0.35
350.	2950.	1275.	165973.	24325.	24397.	24325.	24356.014	2945.657	1274.187	-1476.945	24376.4	2578.628	0.35
400.	3325.	1350.	189683.	27800.	27892.	27800.	27837.530	3319.485	1349.090	-1634.001	27865.0	2879.750	0.35
450.	3750.	1450.	213394.	31275.	31392.	31275.	31320.349	3742.986	1448.950	-1817.178	31356.4	3226.474	0.35

APPENDIX H

LTV BIAXIAL TEST DATA
(CONTRACT NAS8-20160)

LTV BIAXIAL TEST DATA
(CONTRACT NAS8-20160)

The LTV biaxial tests were conducted and subcontracted by LTV-Vought Aenonautics Division, Dallas, Texas. The results of these tests, as submitted to Southwest Research Institute, are contained in this Appendix.

LTV VOUGHT AERONAUTICS DIVISION
Dallas, Texas

Report No. 2-53420/5R-2232
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Title

"BIAXIAL TEST RESULTS ON 2219-T87 ALUMINUM ALLOY"

Conducted For:
Southwest Research Institute
San Antonio, Texas
October 1965

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BIAXIAL TEST RESULTS ON 2219-T87 ALUMINUM ALLOY

INTRODUCTION:

During the period August to October 1965 LTV Vought Aeronautics Division, Dallas, Texas conducted twelve (12) biaxial tests on 2219-T87 aluminum alloy for Southwest Research Institute, San Antonio, Texas under Contract NAS 8-20160. The parent material was furnished by SWR in basic 16.0" x 16.0" x 1/8" sizes to LTV. Six pieces were in the unwelded condition and six pieces were in the welded condition. The welded blanks had weldments parallel with both the longitudinal and transverse grain directions with these weldments intersecting at the predetermined test section locations. LTV machined these specimen blanks into biaxial test specimens configurations (Figure 16 of Reference 1). The machined specimens were instrumented with Baldwin PA-5 (wire) strain gages and tested in the LTV biaxial test machine and facility. The following items summarize the important aspect of this test series:

Test specimen: Figure 16 - reference 1*
Test Temperature: R.T.
Test Procedures: As discussed in section 5 of reference 1*

*-Reference 1 - AFML-TR-65-140 (May 1965), cryogenic design data for materials subjected to uniaxial and multiaxial stress fields (LTV Research)

- A copy of this document was given to Mr. E. B. Morris of SWR on 29 Sept. 1965 when he visited LTV to observe a portion of the testing effort.

TEST RESULTS:

The test results are shown in Figures 1 through 12 of this report. These figures are basic load-strain and stress-strain curves for each of the twelve tests. The load strain curves are the raw data that are used to obtain biaxial stress-strain curves. The procedure for this conversion is covered in Section 5 of Reference 1 (Figures 20 and 21 of Reference 1). A summary of the critical mechanical properties for each test is shown in each figure. The uniaxial data (E_L, E_T, μ_L, μ_T) used to establish initial strain ratios to obtain the 2:1 stress fields were furnished by SWR and are also shown on each of the test data figures. These ratios were:

WELDED: $e_1/e_2 = 3.45$
UNWELDED: $e_1/e_2 = 4.14$

The 1:1 biaxial tests were conducted by maintaining equal loads in each of the principal stress directions.

The tests were conducted without any real problem as illustrated by the plotted data and the failed biaxial specimens that are being returned to SWR by separate package. The 1:1 tests are closely characteristic in form with the welded specimens illustrating a lower stress-strain relationship than the unwelded specimens. The 2:1 tests in the unwelded condition have a slight strain reversal in the near failure zone and this is probably due to slight errors in POISSON's ratio values and its affect on calculation of the initial strain ratios. However, this does not change the stress-state very much. This can be observed if one plots e_1/e_2 versus σ_1/σ_2 and this plot illustrates the relative insensitivity of strain state to stress-state in this 2:1 zone. In addition the affects of early plastic yielding in the minimum stress direction was observed in the 2:1 weldment tests (see Figure 10, 11 and 12). This condition complicated the 2:1 biaxial testing techniques since a basic elastic condition did not exist in the minimum stress direction. Therefore, in light of this condition it was recommended by LTV and approved by SWR that the basic load ratio required to obtain initial strain states (2:1 stress state) be maintained all the way to failure. This approach certainly approximates the desired stress state very closely and allowed the welded material to strain as it would under actual pressure vessel (cylinder) conditions:

CONCLUSIONS:

1. The tests results are presented in Figures 1 through 12

2. Use of the intersecting weldment conditions creates a very severe material condition that results in large reductions in material allowables under biaxial stress fields.

3. Unwelded material properties for the 1:1 stress state are about equal to what biaxial theory would predict.

4. Unwelded material properties for the 2:1 stress state are a little lower for two tests than theory would predict and about equal to theory for one test.

5. Poisson ratio values from uniaxial tests seem a little low (usually in the 0.30 to 0.33 range for this alloy). Likewise uniaxial modulus values in the welded condition also seem a little low. The values are very critical in developing biaxial data whether in the cross-shaped specimen or in tubular specimens.

6. The following page summarizes the basic equational forms used in this effort.

BASIC EQUATIONS

FOR 1:1 STRESS STATE:

$$e_1 = \frac{1}{E_1}(\sigma_1 - \mu_1\sigma_2)$$

$$e_2 = \frac{1}{E_2}(\sigma_2 - \mu_2\sigma_1)$$

$$\therefore\ e_1 = \frac{\sigma_1}{E_1}(1 - \mu_1)$$

$$e_2 = \frac{\sigma_2}{E_2}(1 - \mu_2)$$

SO: $$\sigma_1 = \frac{e_1 E_1}{1 - \mu_1}$$

$$\sigma_2 = \frac{e_2 E_2}{1 - \mu_2}$$

BUT: $\sigma_1 = \sigma_2$

μ_1 = POISSON's Ratio Developed by load in the (one) direction.

FOR 2:1 STRESS STATE:

$$e_1 = \frac{1}{E_1}(\sigma_1 - \mu_1 \sigma_2)$$

$$e_2 = \frac{1}{E_2}(\sigma_2 - \mu_2 \sigma_1)$$

$$\therefore\ e_1 = \frac{\sigma_1}{E_1}(1 - 0.5\mu_1)$$

$$e_2 = \frac{\sigma_2}{E_2}(1 - 2\mu_2)$$

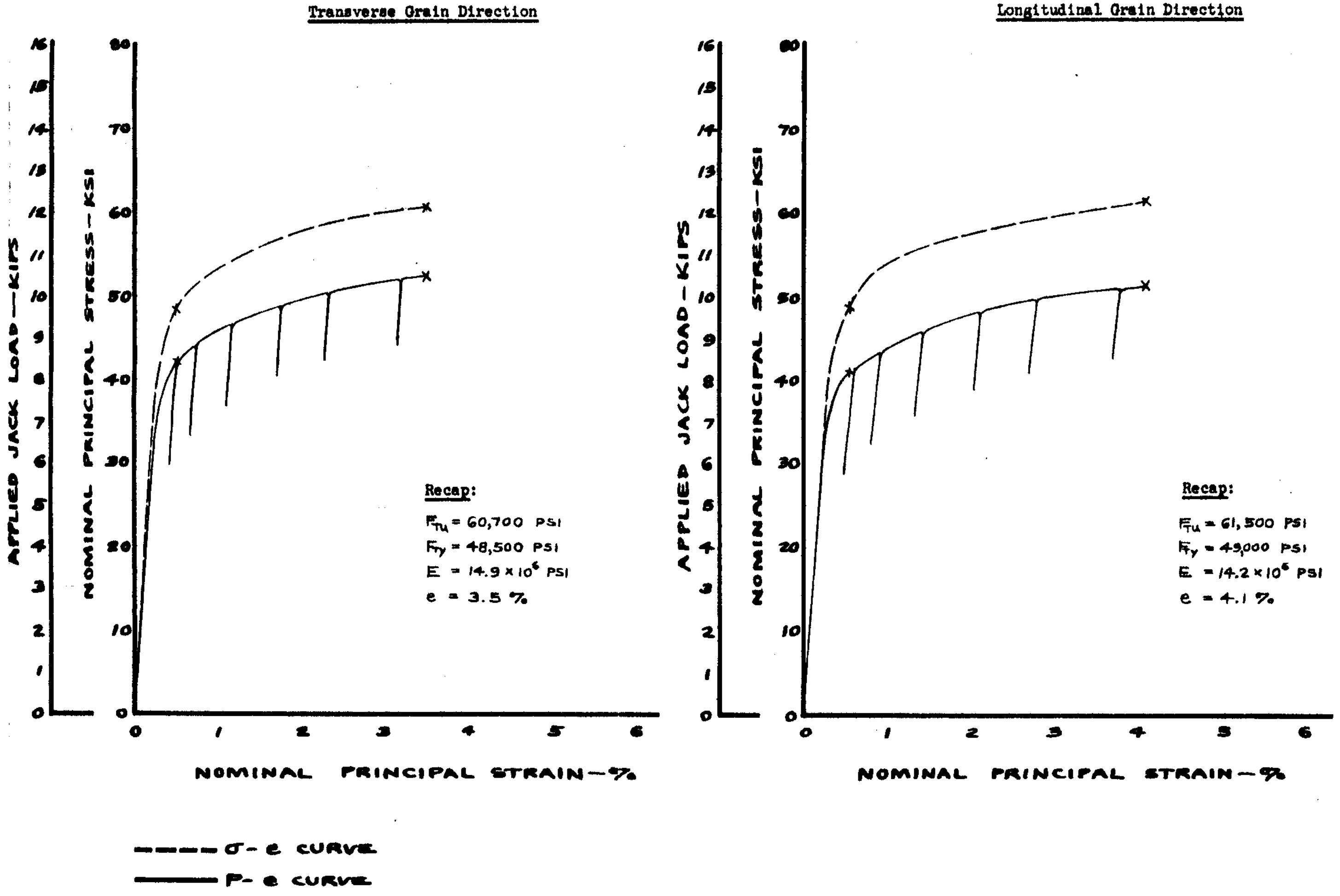
SO: $$\sigma_1 = \frac{e_1E_1}{1 - 0.5\mu_1}$$

$$\sigma_2 = \frac{e_2E_2}{1 - 2\mu_2}$$ or also $$\sigma_1 = \frac{e_2E_2}{0.5 - \mu_2}$$

BUT: $\sigma_1 = 2\sigma_2$

FIGURE 1 - 1:1 BIAXIAL STRESS-STRAIN CURVES FOR UNWELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-1


Transverse Grain Direction

Recap:
F_{Tu} = 60,700 PSI
F_{Ty} = 48,500 PSI
E = 14.9×10^6 PSI
e = 3.5 %

Longitudinal Grain Direction

Recap:
F_{Tu} = 61,500 PSI
F_{Ty} = 49,000 PSI
E = 14.2×10^6 PSI
e = 4.1 %

Uniaxial Data
for Comparison
(Unwelded)

$E_L = 10.1 \times 10^6$ PSI

$E_T = 10.6 \times 10^6$ PSI

$\mu_L = .288$

$\mu_T = .287$

F_{Ty} = 54.9 KSI (L)

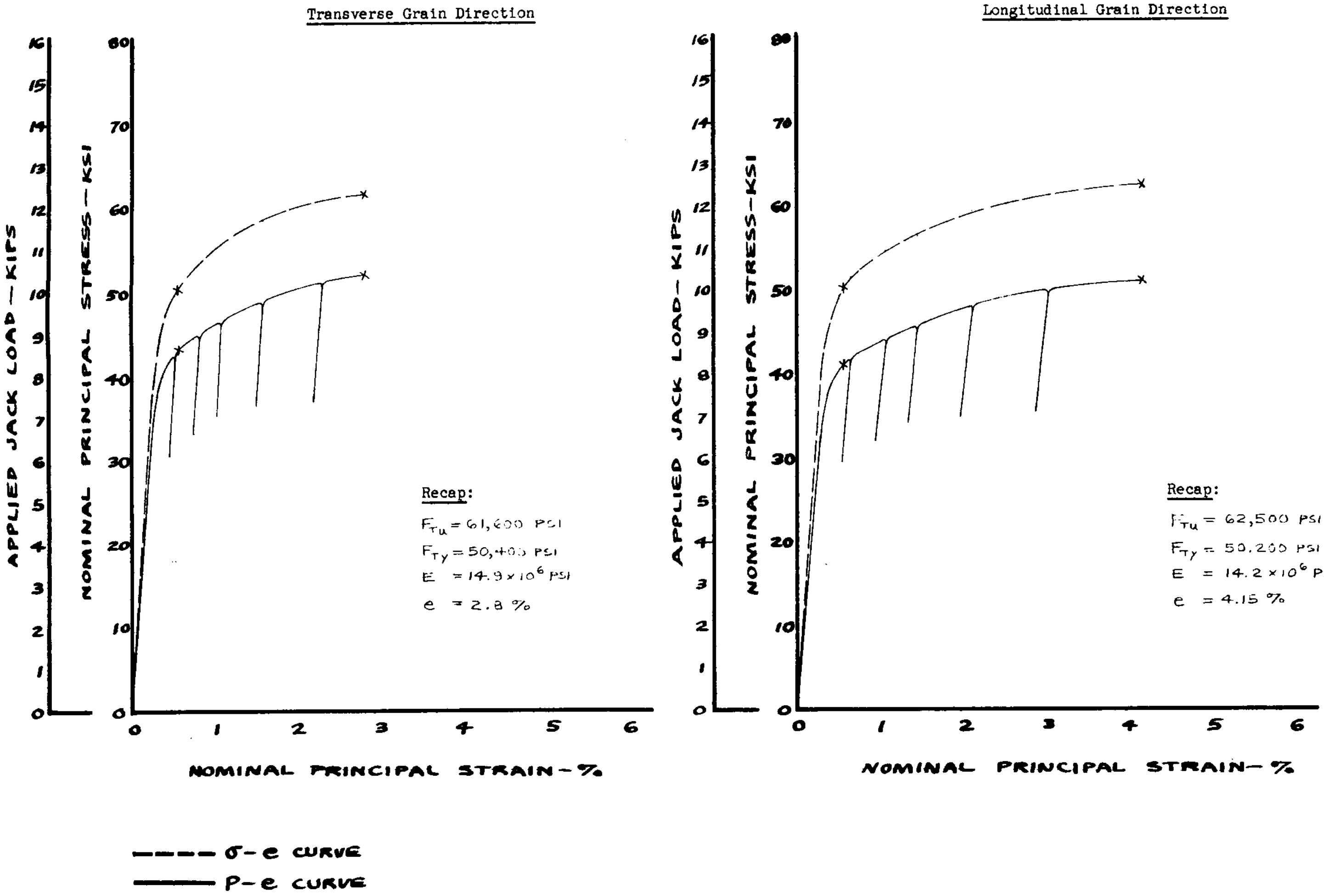
F_{Tu} = 65.8 KSI (L)

F_{Ty} = 56.1 KSI (T)

F_{Tu} = 68.4 KSI (T)

FIGURE 2 - 1:1 BIAXIAL STRESS-STRAIN CURVES FOR UNWELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-2



Recap:
F_{Tu} = 61,600 PSI
F_{Ty} = 50,400 PSI
E = 14.9×10^6 PSI
e = 2.8 %

Recap:
F_{Tu} = 62,500 PSI
F_{Ty} = 50,200 PSI
E = 14.2×10^6 PSI
e = 4.15 %

Uniaxial Data for Comparison (Unwelded)

$E_L = 10.1 \times 10^6$ PSI
$E_T = 10.6 \times 10^6$ PSI

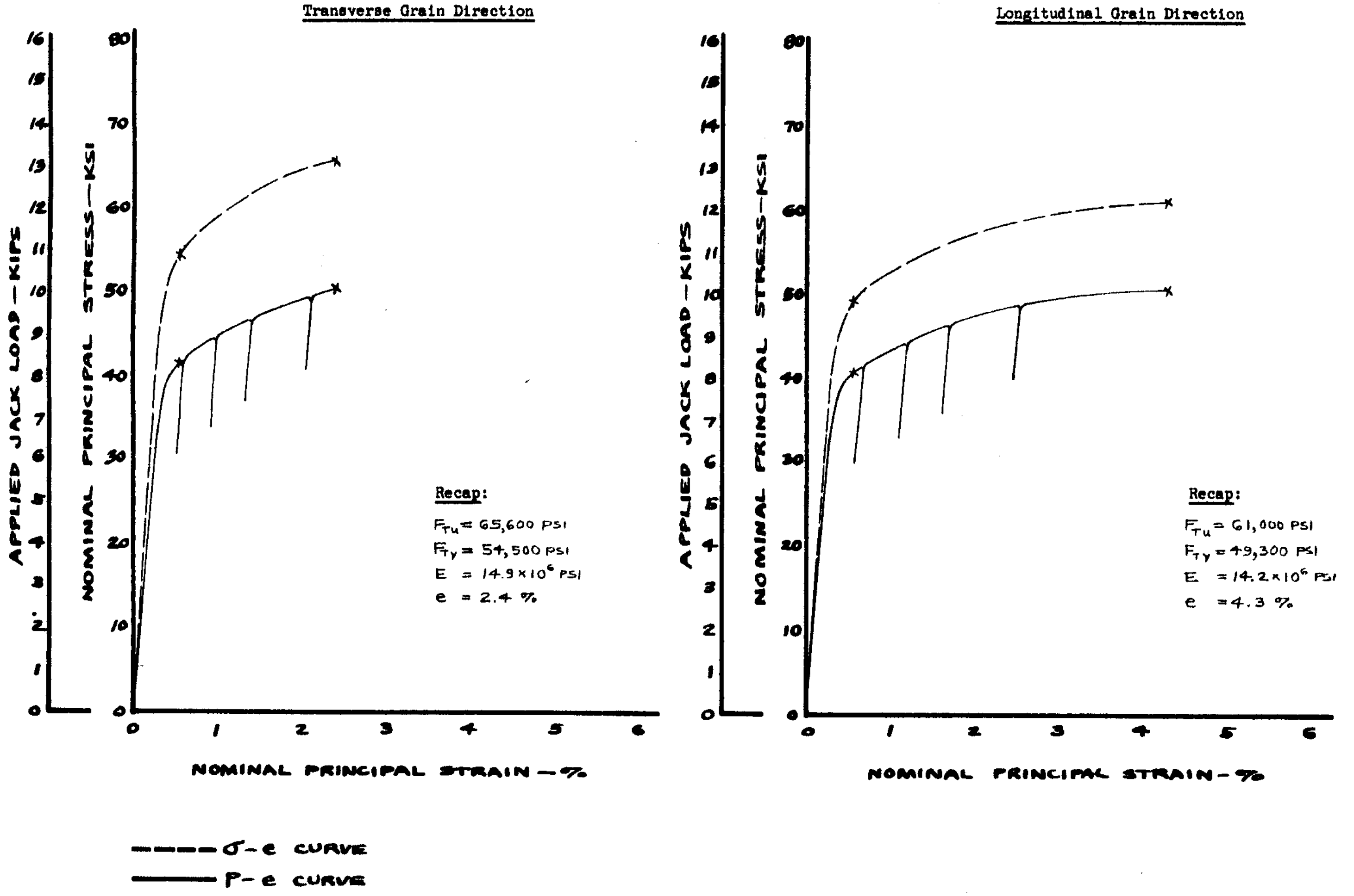
$\mu_L = .288$
$\mu_T = .287$

$F_{Ty} = 54.9$ KSI (L)
$F_{Tu} = 65.8$ KSI (L)

$F_{Ty} = 56.1$ KSI (T)
$F_{Tu} = 68.4$ KSI (T)

FIGURE 3 - 1:1 BIAXIAL STRESS-STRAIN CURVES FOR UNWELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-3



Transverse Grain Direction

Longitudinal Grain Direction

Recap:
F_{Tu} = 65,600 PSI
F_{Ty} = 54,500 PSI
E = 14.9×10^6 PSI
e = 2.4 %

Recap:
F_{Tu} = 61,000 PSI
F_{Ty} = 49,300 PSI
E = 14.2×10^6 PSI
e = 4.3 %

Uniaxial Data
for Comparison
(Unwelded)

$E_L = 10.1 \times 10^6$ PSI
$E_T = 10.6 \times 10^6$ PSI

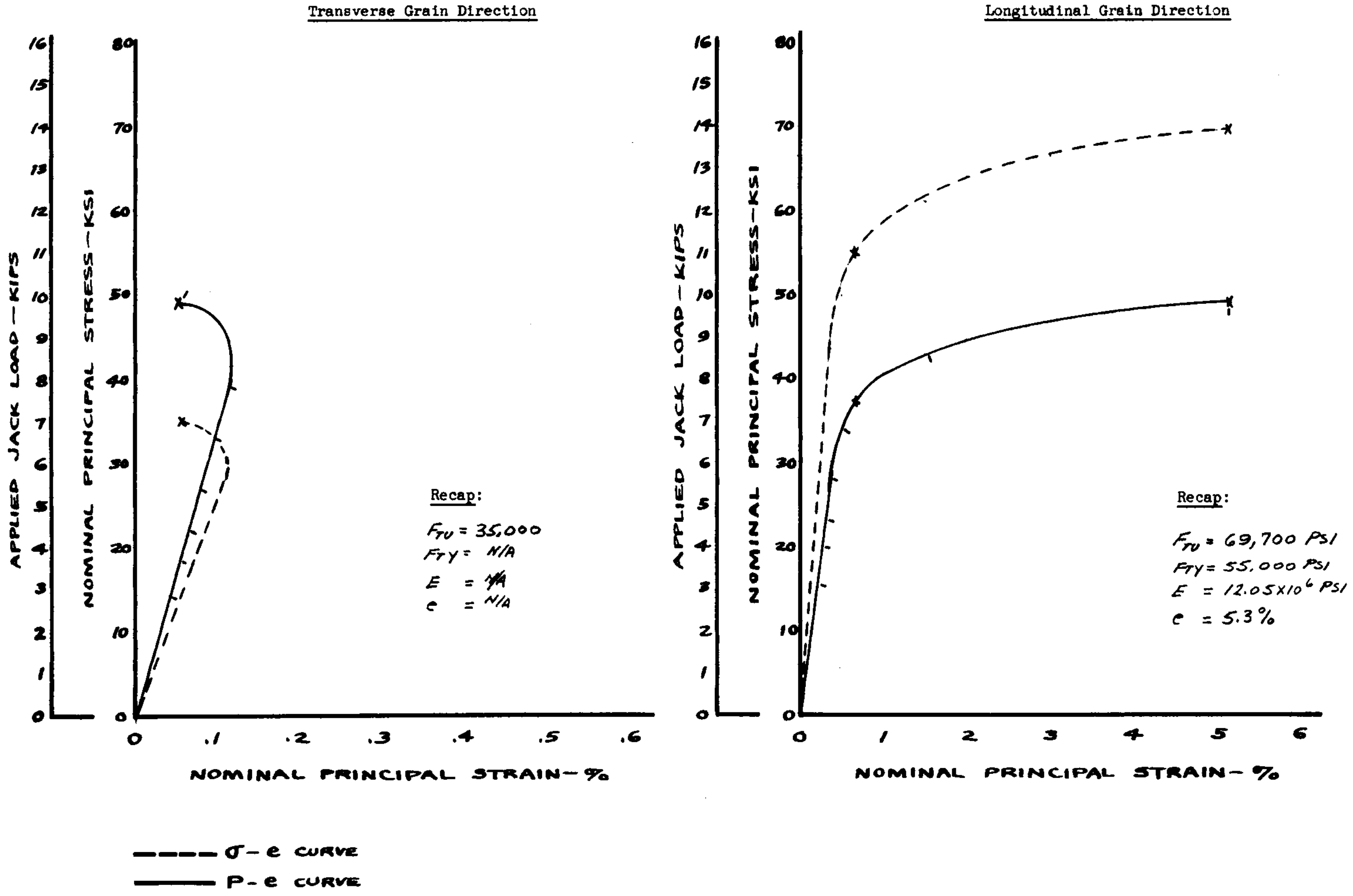
$\mu_L = .288$
$\mu_T = .287$

$F_{Ty} = 54.9$ KSI (L)
$F_{Tu} = 65.8$ KSI (L)

$F_{Ty} = 56.1$ KSI (T)
$F_{Tu} = 68.4$ KSI (T)

FIGURE 4 - 2:1 BIAXIAL STRESS-STRAIN CURVES FOR UNWELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-4



Recap:

F_{TU} = 35,000
F_{TY} = N/A
E = N/A
e = N/A

Recap:

F_{TU} = 69,700 PSI
F_{TY} = 55,000 PSI
E = 12.05x10^6 PSI
e = 5.3%

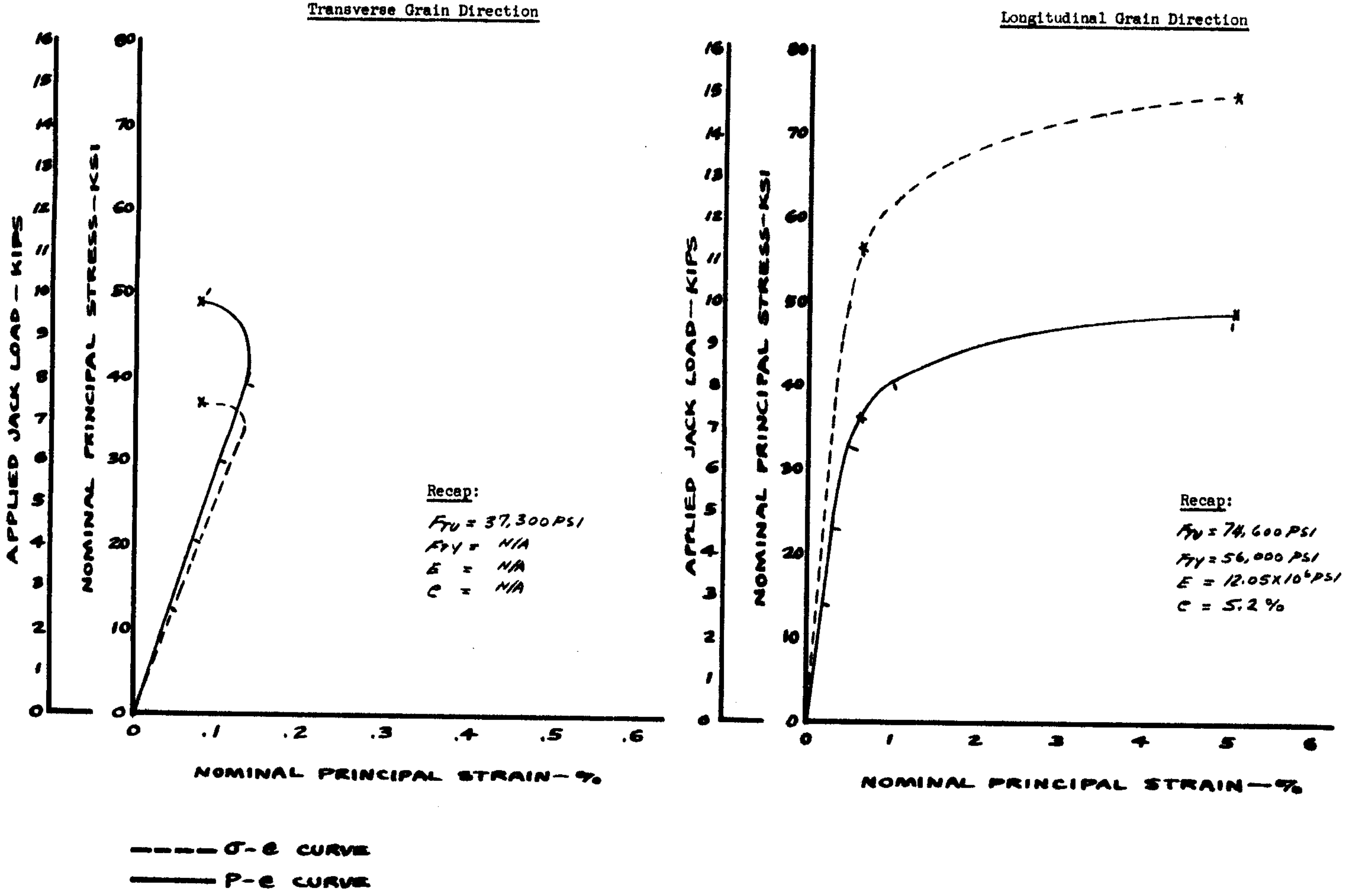
Uniaxial Data
for Comparison
(Unwelded)

E_L = 10.1x10^6 PSI
E_T = 10.6x10^6 PSI
μ_L = 0.288
μ_T = 0.287

F_{TY} = 54.9 KSI (L)
F_{TU} = 65.8 KSI (L)
F_{TY} = 56.1 KSI (T)
F_{TU} = 68.4 KSI (T)

FIGURE 5 - 2:1 BIAXIAL STRESS-STRAIN CURVES FOR UNWELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-5



Recap:
F_{tu} = 37,300 PSI
F_{ty} = N/A
E = N/A
e = N/A

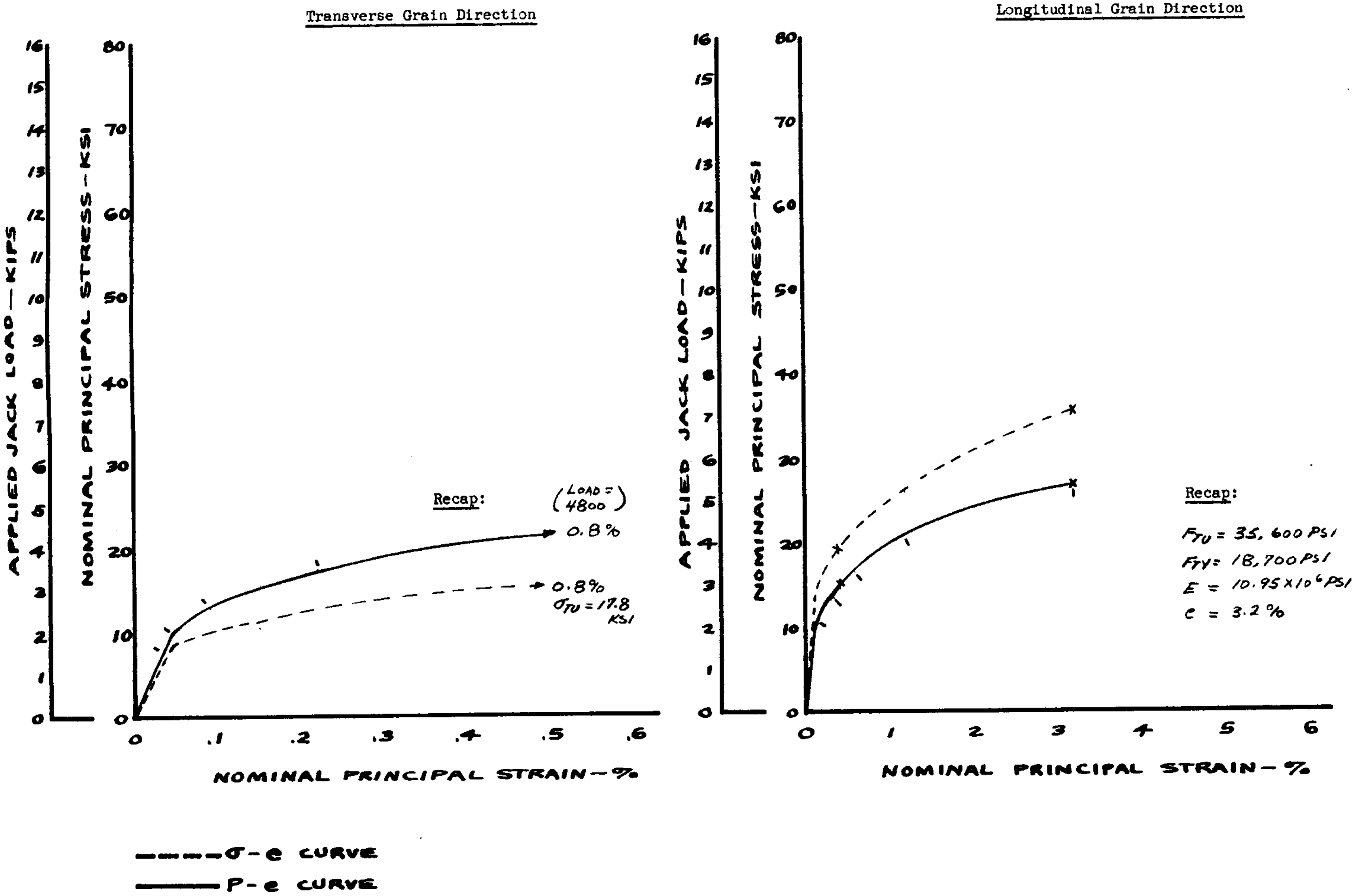
Recap:
F_{tu} = 74,600 PSI
F_{ty} = 56,000 PSI
E = 12.05×10^6 PSI
e = 5.2 %

Uniaxial Data
for Comparison
(Unwelded)

$E_L = 10.1 \times 10^6$ PSI
$E_T = 10.6 \times 10^6$ PSI
$\mu_L = 0.288$
$\mu_T = 0.287$
F_{ty} = 54.9 KSI (L)
F_{tu} = 65.8 KSI (L)
F_{ty} = 56.1 KSI (T)
F_{tu} = 68.4 KSI (T)

FIGURE 12 - 2:1 BIAXIAL STRESS-STRAIN CURVES FOR
WELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-12



Recap:

Recap:

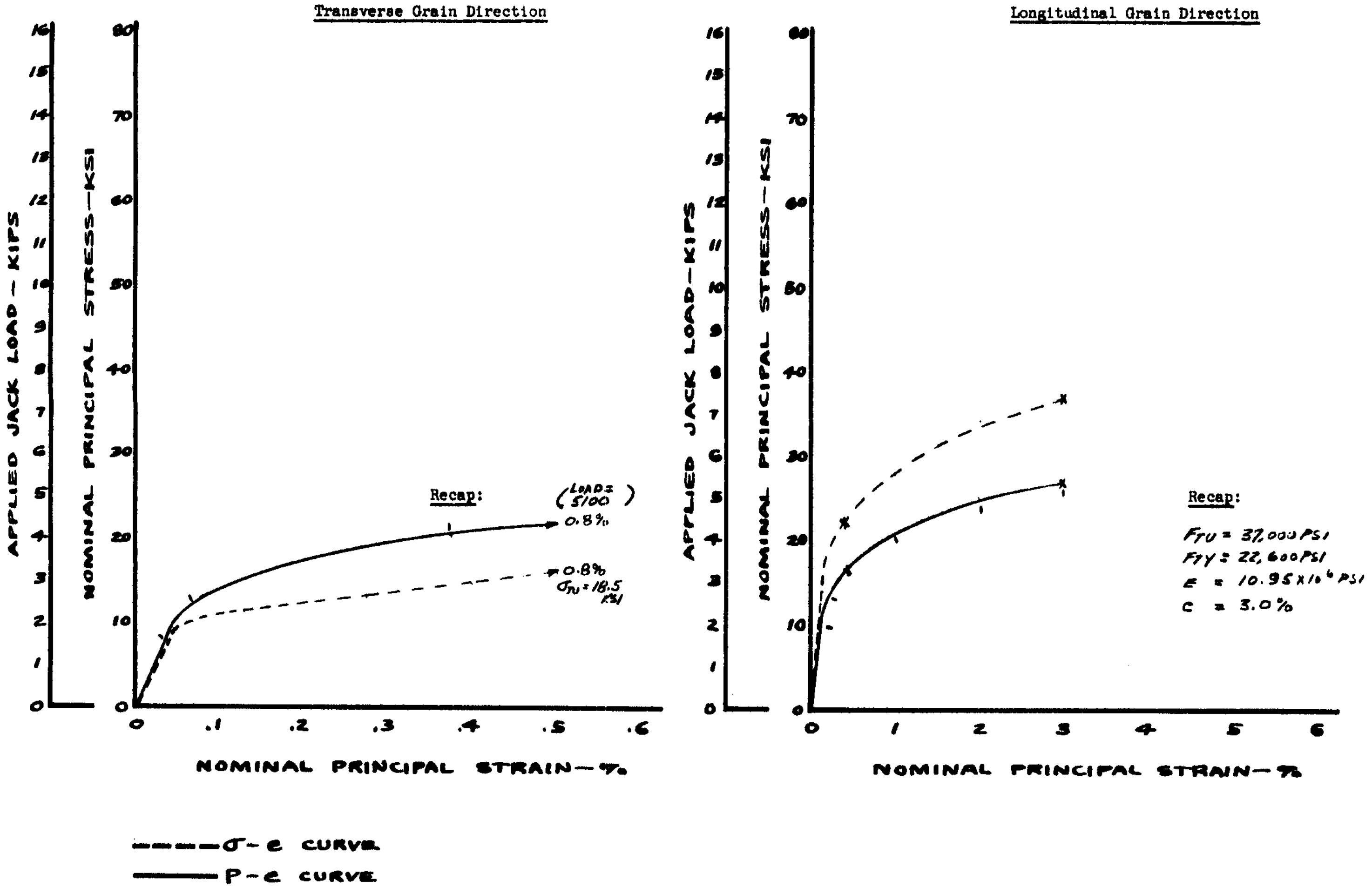
F_{TU} = 35,600 PSI
F_{TY} = 18,700 PSI
E = 10.95×10^6 PSI
e = 3.2 %

Uniaxial Data for Comparison (Welded)

$E_L = 9.48 \times 10^6$ PSI
$E_T = 9.05 \times 10^6$ PSI
$\mu_L = 0.267$
$\mu_T = 0.259$
$F_{TY} = 16.7$ KSI (L)
$F_{TU} = 36.5$ KSI (L)
$F_{TY} = 17.5$ KSI (T)
$F_{TU} = 37.8$ KSI (T)

FIGURE 11 - 2:1 BIAXIAL STRESS-STRAIN CURVES FOR
WELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-11

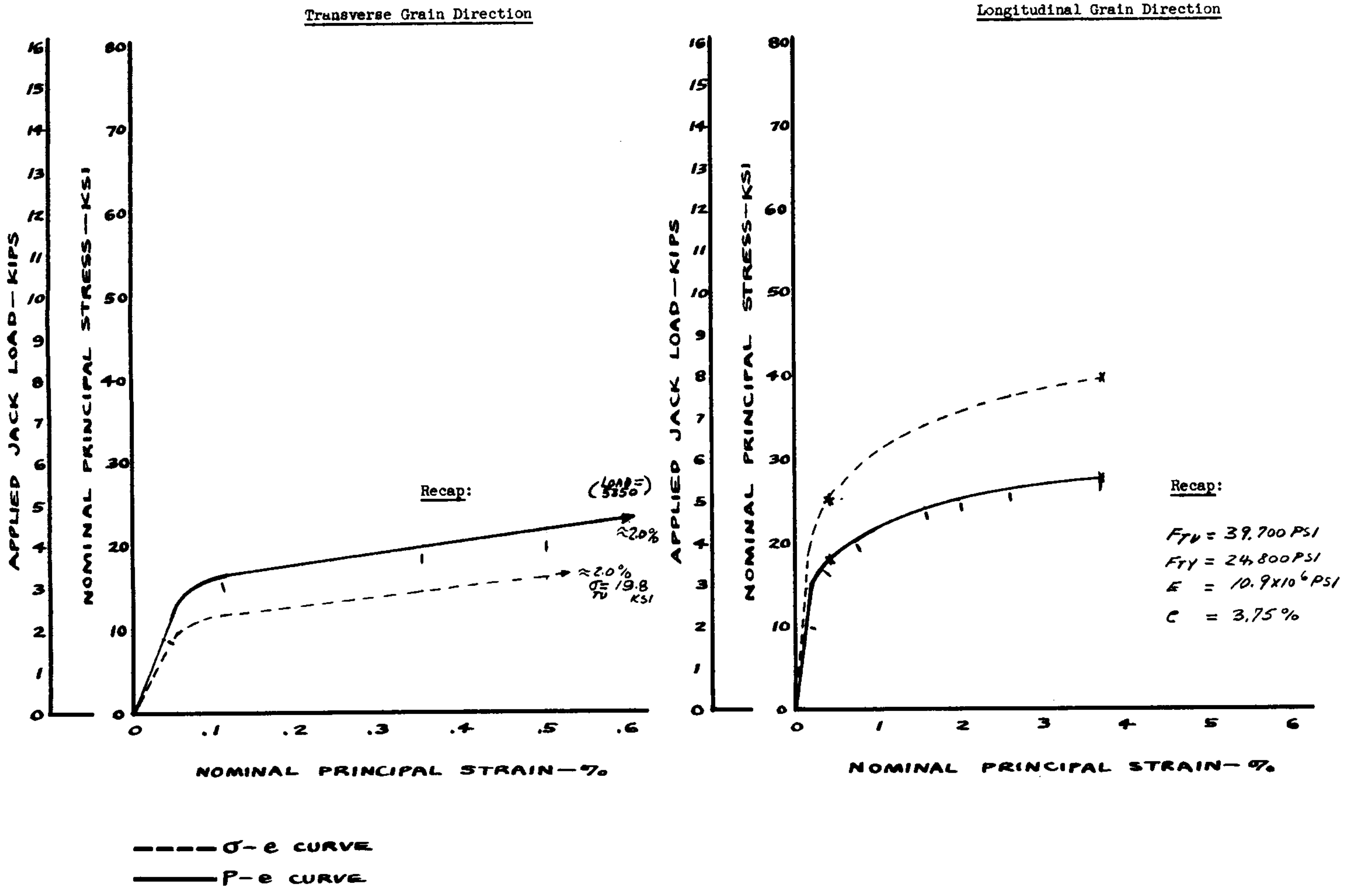


Uniaxial Data
for Comparison
(Welded)

$E_L = 9.48 \times 10^6$ PSI
$E_T = 9.05 \times 10^6$ PSI
$\mu_L = 0.267$
$\mu_T = 0.259$
$F_{TY} = 16.7$ KSI (L)
$F_{TU} = 36.5$ KSI (L)
$F_{TY} = 17.5$ KSI (T)
$F_{TU} = 37.5$ KSI (T)

FIGURE 10 - 2:1 BIAXIAL STRESS-STRAIN CURVES FOR WELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-10



Recap:

Recap:

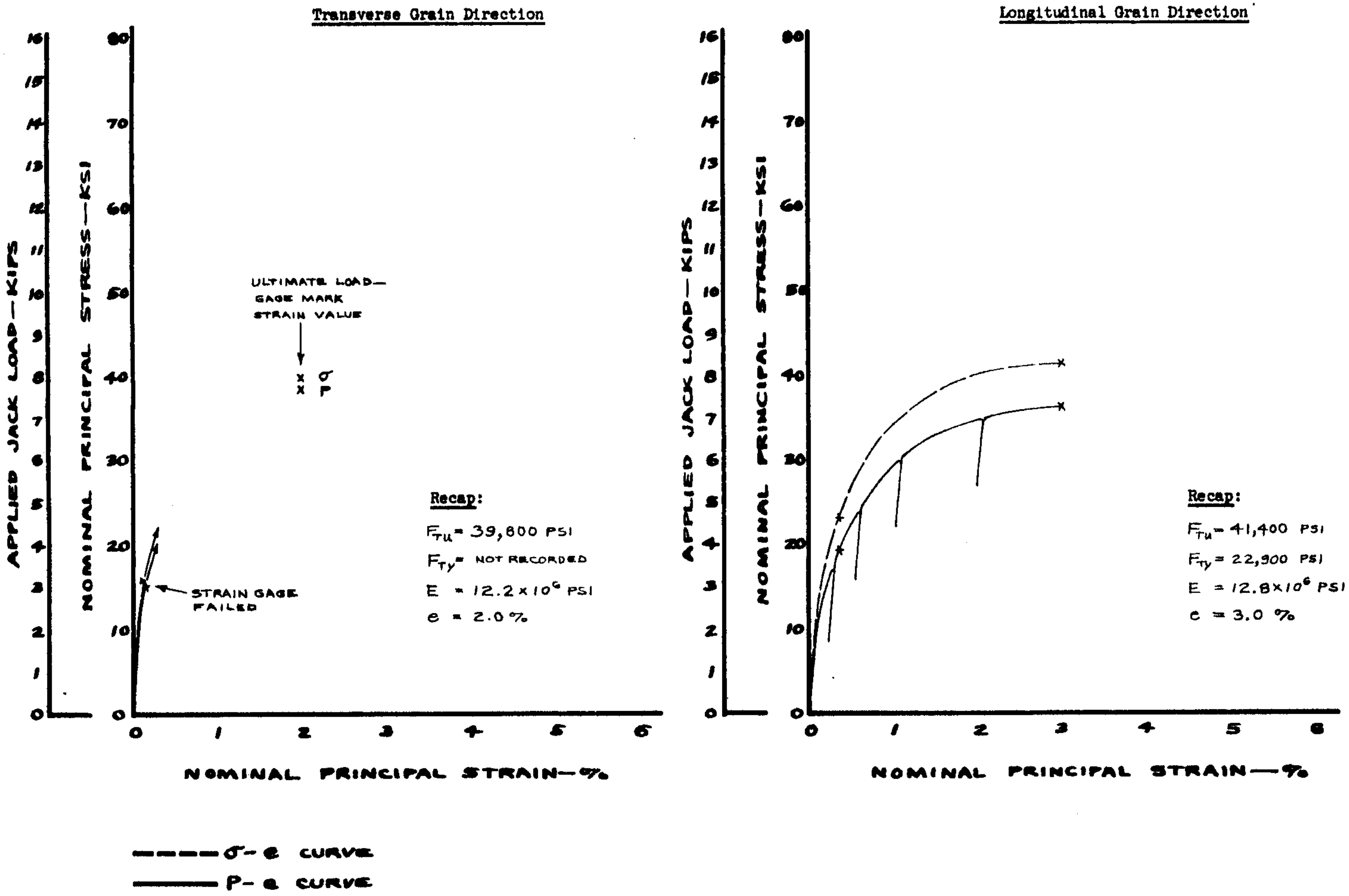
F_{TU} = 39,700 PSI
F_{TY} = 24,800 PSI
E = 10.9×10⁶ PSI
e = 3.75%

Uniaxial Data for Comparison (Welded)

E_L = 9.48×10⁶ PSI
E_T = 9.05×10⁶ PSI
μ_L = 0.267
μ_T = 0.259
F_{TY} = 16.7 KSI (L)
F_{TU} = 36.5 KSI (L)
F_{TY} = 17.5 KSI (T)
F_{TU} = 37.8 KSI (T)

FIGURE 9 - 1:1 BIAXIAL STRESS-STRAIN CURVES FOR WELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-9



Transverse Grain Direction

Longitudinal Grain Direction

Recap: (Transverse)

F_{Tu} = 39,800 PSI
F_{Ty} = NOT RECORDED
E = 12.2×10^6 PSI
e = 2.0 %

Recap: (Longitudinal)

F_{Tu} = 41,400 PSI
F_{Ty} = 22,900 PSI
E = 12.8×10^6 PSI
e = 3.0 %

Uniaxial Data
for Comparison
(Welded)

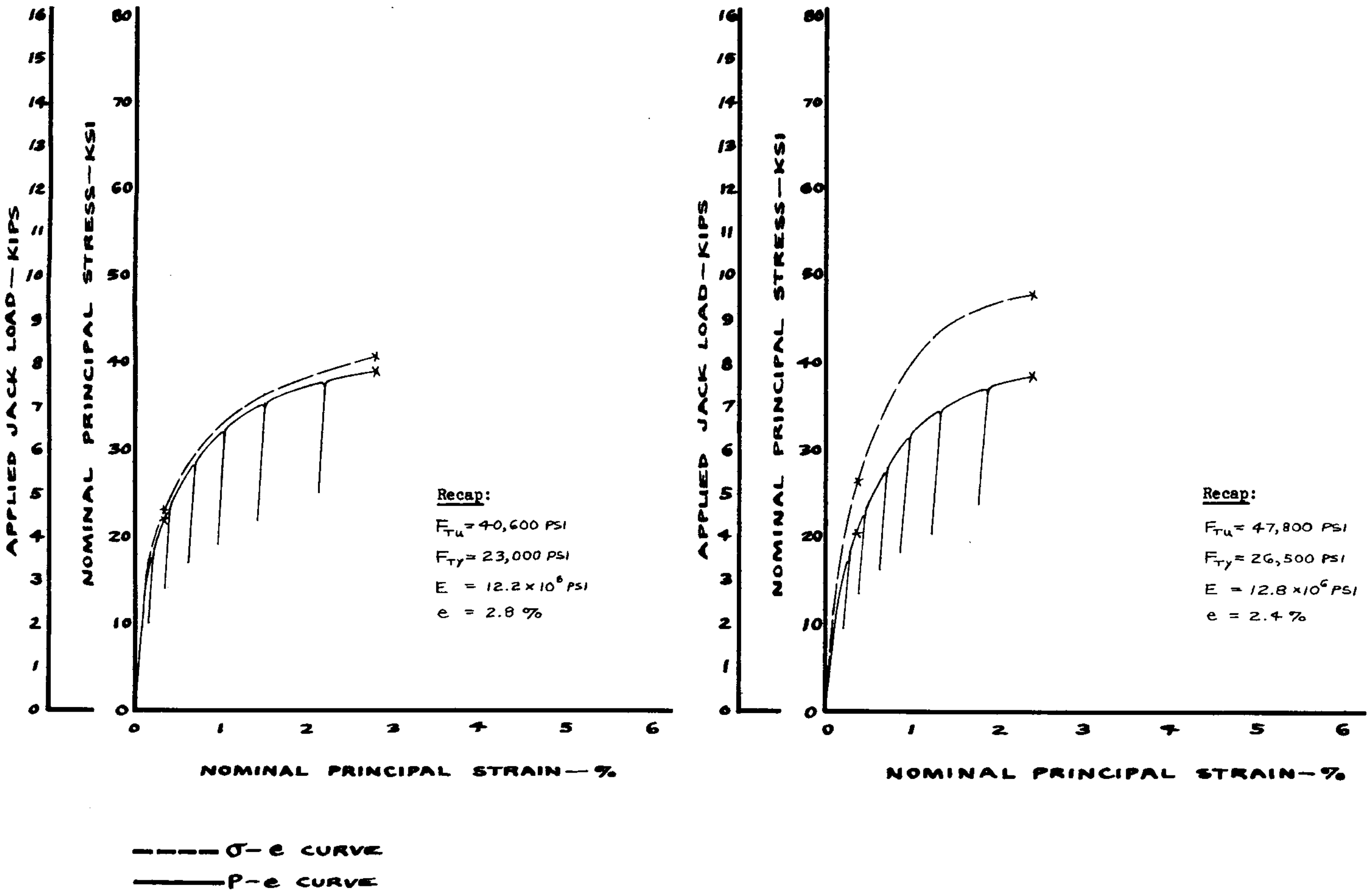
$E_L = 9.48 \times 10^6$ PSI
$E_T = 9.05 \times 10^6$ PSI
$\mu_L = .267$
$\mu_T = .259$
$F_{Ty} = 16.7$ KSI (L)
$F_{Tu} = 36.5$ KSI (L)
$F_{Ty} = 17.5$ KSI (T)
$F_{Tu} = 37.8$ KSI (T)

FIGURE 8 - 1:1 BIAXIAL STRESS-STRAIN CURVES FOR
WELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-8

Transverse Grain Direction

Longitudinal Grain Direction



Recap:
F_{Tu} = 40,600 PSI
F_{Ty} = 23,000 PSI
E = 12.2×10^6 PSI
e = 2.8 %

Recap:
F_{Tu} = 47,800 PSI
F_{Ty} = 26,500 PSI
E = 12.8×10^6 PSI
e = 2.4 %

Uniaxial Data
for Comparison
(Welded)

$E_L = 9.48 \times 10^6$ PSI
$E_T = 9.05 \times 10^6$ PSI

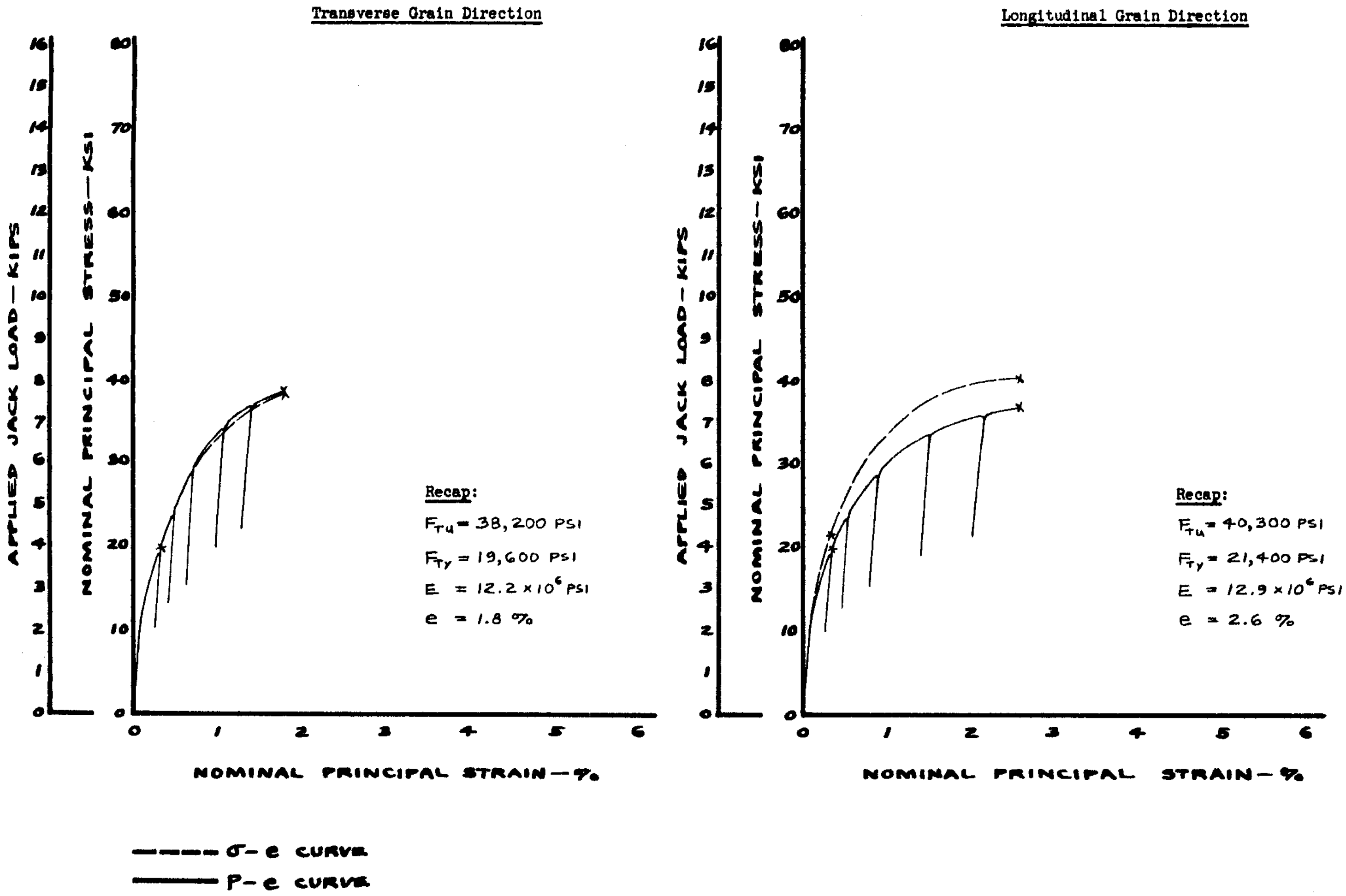
$\mu_L = .267$
$\mu_T = .259$

F_{Ty} = 16.7 KSI (L)
F_{Tu} = 36.5 KSI (L)

F_{Ty} = 17.5 KSI (T)
F_{Tu} = 37.8 KSI (T)

FIGURE 7 - 1:1 BIAXIAL STRESS-STRAIN CURVES FOR
WELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-7



Uniaxial Data
for Comparison
(Welded)

E_L = 9.48 × 10^6 PSI

E_T = 9.05 × 10^6 PSI

μ_L = .267

μ_T = .259

F_{Ty} = 16.7 KSI (L)

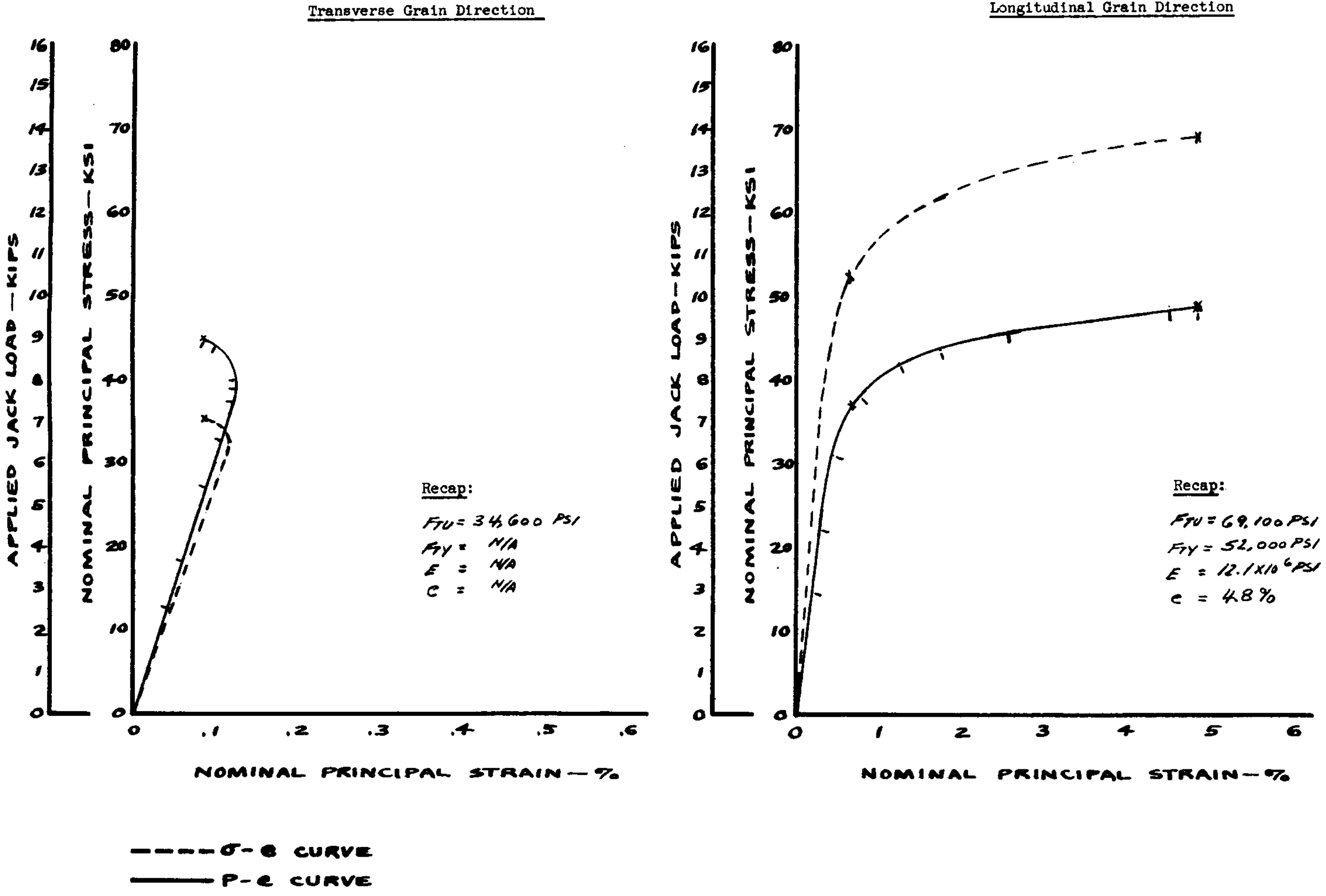
F_{Tu} = 36.5 KSI (L)

F_{Ty} = 17.5 KSI (T)

F_{Tu} = 37.8 KSI (T)

FIGURE 6 - 2:1 BIAXIAL STRESS-STRAIN CURVES FOR UNWELDED 2219-T87 ALUMINUM ALLOY

Test Temperature: Room Temperature
Specimen No.: TC-6



Recap:
F_{TU} = 34,600 PSI
F_{TY} = N/A
E = N/A
e = N/A

Recap:
F_{TU} = 69,100 PSI
F_{TY} = 52,000 PSI
E = 12.1×10^6 PSI
e = 4.8 %

Uniaxial Data
for Comparison
(Unwelded)

$E_L = 10.1 \times 10^6$ PSI
$E_T = 10.6 \times 10^6$ PSI
$\mu_L = 0.288$
$\mu_T = 0.287$
$F_{TY} = 54.9$ KSI (L)
$F_{TU} = 65.8$ KSI (L)
$F_{TY} = 56.1$ KSI (T)
$F_{TU} = 68.4$ KSI (T)

APPENDIX I

PHASE II TENSILE AND HYDRAULIC BULGE TEST DATA (CONTRACT NAS8-20160)

PHASE II TENSILE AND HYDRAULIC BULGE TEST DATA
(CONTRACT NAS8-20160)

The results of the individual uniaxial tensile tests and hydraulic bulge tests conducted in the evaluation of the mechanical properties of aluminum alloy weldments (Phase II Contract NAS8-20160) are presented in Tables I-1 through I-9. The computed mean value, standard deviation and lower tolerance limit for each property are also included in the tables. These computations were carried out on a GE-225 digital computer in accordance with the procedures described in Appendix K. Tables I-1 through I-9 are reproduced from the computer print-out sheets and the letter symbols appearing in the tables are as follows:

Y	0.2% Offset Yield Strength, ksi
$YBAR	Average Value of Yield Strength, ksi
$SY	Standard Deviation of Yield Strength, ksi
$LTLY	Lower Tolerance Limit of Yield Strength, ksi
U	Ultimate Tensile Strength, ksi
$UBAR	Average Value of Ultimate Strength, ksi
$SU	Standard Deviation of Ultimate Strength, ksi
$LTLU	Lower Tolerance Limit of Ultimate Strength, ksi
E	Elongation in Two Inches, %
$EBAR	Average Value of Elongation, %
$SE	Standard Deviation of Elongation, %

The floating decimal point system was used in the computations and all values in the tables are given in powers of ten. For example:

5.2500000 + 01 = 52.500000

7.0454965 - 01 = 0.70454965

The specimen identification is contained in the first column. The last digit of this number is a tensile specimen sequence number. The remaining digits are the bulge panel sequence number.

TABLE I-1.

UNIAXIAL TENSILE TEST RESULTS ON PARENT ALUMINUM ALLOYS

```
          NUMBER           Y               U               E
   LAPEL 2219-T87 PARENT METAL
                21    5.2500000+01    6.5000000+01    9.8000000+00
                22    5.2500000+01    6.4800000+01    1.0500000+01
                23    5.3900000+01    6.5800000+01    1.1200000+01
                24    5.3900000+01    6.5600000+01    1.1200000+01
                25    5.3700000+01    6.5300000+01    1.1200000+01
                71    5.4100000+01    6.5800000+01    1.1300000+01
                72    5.4000000+01    6.5500000+01    1.1300000+01
                73    5.3700000+01    6.5400000+01    1.0300000+01
                74    5.3900000+01    6.5400000+01    1.0400000+01
                75    5.4100000+01    6.5000000+01    1.0400000+01
                81    5.4700000+01    6.6700000+01    1.0500000+01
                82    5.4500000+01    6.6700000+01    1.0300000+01
                83    5.4800000+01    6.6600000+01    1.1000000+01
                84    5.4700000+01    6.6700000+01    1.1000000+01
                85    5.4600000+01    6.6800000+01    1.0700000+01
     5.3973333+01 $YBAR  7.0454965-01 $SY  5.1493318+01 $LTLY
     6.5806666+01 $UBAR  7.0963627-01 $SU  6.3308746+01 $LTLU
     1.0740000+01 $EBAR  4.6414451-01 $SE

   LABEL 2014-T6 PARENT METAL
                81    6.5000000+01    6.9900000+01    1.0100000+01
                82    6.4700000+01    7.0300000+01    9.0000000+00
                83    6.9200000+01    7.4400000+01    8.8000000+00
                84    6.4500000+01    6.9200000+01    9.2000000+00
                85    6.6100000+01    7.1000000+01    8.4000000+00
                91    6.4800000+01    7.0200000+01    9.9000000+00
                92    6.4700000+01    6.9800000+01    1.0200000+01
                93    6.4600000+01    6.9600000+01    9.4000000+00
                94    6.0000000+01    6.9400000+01    9.8000000+00
                95    6.5200000+01    7.0600000+01    8.9000000+00
               101    6.5100000+01    7.0400000+01    8.6000000+00
               102    6.5000000+01    7.0000000+01    9.8000000+00
               103    6.4700000+01    7.0000000+01    9.3000000+00
               104    6.4900000+01    7.0100000+01    9.2000000+00
               105    6.6300000+01    7.1700000+01    9.0000000+00
     6.4986666+01 $YBAR  1.8189109+00 $SY  5.8584100+01 $LTLY
     7.0440000+01 $UBAR  1.2597070+00 $SU  6.6005831+01 $LTLU

     9.3066666+00 $EBAR  5.4963257-01 $SE
   LABEL 7106-T63 PARENT METAL
                21    5.7300000+01    6.4600000+01    1.1500000+01
                22    5.7300000+01    6.4400000+01    1.0400000+01
                23    5.7300000+01    6.4600000+01    1.0500000+01
                24    5.6900000+01    6.4400000+01    1.1200000+01
                25    5.7400000+01    6.4800000+01    1.1200000+01
                31    5.8300000+01    6.5800000+01    1.1300000+01
                32    5.8100000+01    6.5600000+01    1.0800000+01
                33    5.8100000+01    6.5600000+01    1.0400000+01
                34    5.7700000+01    6.5100000+01    1.0900000+01
                35    5.7700000+01    6.4800000+01    1.0800000+01
                51    5.7800000+01    6.4900000+01    1.1300000+01
                52    5.7600000+01    6.4900000+01    1.0800000+01
                53    5.7900000+01    6.5400000+01    1.0400000+01
                54    5.7500000+01    6.3900000+01    1.0900000+01
                55    5.7700000+01    6.4800000+01    1.0200000+01
     5.7640000+01 $YBAR  3.7189469-01 $SY  5.6330930+01 $LTLY
     6.4906666+01 $UBAR  5.2027965-01 $SU  6.3075282+01 $LTLU
     1.0840000+01 $EBAR  3.9964441-01 $SE
```

TABLE I-2.

UNIAXIAL TENSILE TEST RESULTS ON HEAT TREATED PARENT ALUMINUM ALLOYS

```
          NUMBER           Y               U               E
   LABEL 2219-T87 PARENT METAL ANN
                 1    1.4800000+01    3.0000000+01    2.0300000+01
                 2    1.4700000+01    3.1000000+01    2.0000000+01
                 3    1.4900000+01    3.1000000+01    2.0200000+01
                 4    1.4800000+01    3.1000000+01    2.0000000+01
                 5    1.5100000+01    3.1100000+01    1.8800000+01
     1.4860000+01 $YBAR  1.5165987-01 $SY  1.3987956+01 $LTLY
     3.0820000+01 $UBAR  4.6043239-01 $SU  2.8172514+01 $LTLU
     1.9860000+01 $EBAR  6.0663163-01 $SE

   LABEL 2219-T87 PARENT METAL SR
                 1    4.0400000+01    5.6200000+01    1.1000000+01
                 2    3.9900000+01    5.5700000+01    1.1000000+01
                 3    4.0200000+01    5.6300000+01    1.1500000+01
                 4    4.1300000+01    5.7500000+01    1.1200000+01
                 5    4.0600000+01    5.6700000+01    1.2000000+01
     4.0480000+01 $YBAR  5.2630830-01 $SY  3.7453727+01 $LTLY
     5.6480000+01 $UBAR  6.7231204-01 $SU  5.2614206+01 $LTLU
     1.1340000+01 $EBAR  4.2190156-01 $SE

   LABEL 2014-T6 PARENT METAL ANN
                 1    1.0500000+01    2.9600000+01    1.9900000+01
                 2    1.2400000+01    2.9600000+01    1.8000000+01
                 3    1.2200000+01    2.9700000+01    1.8800000+01
                 4    1.2300000+01    2.9600000+01    1.8800000+01
                 5    1.3200000+01    3.0300000+01    1.8300000+01
     1.2120000+01 $YBAR  9.8843395-01 $SY  6.4365048+00 $LTLY
     2.9760000+01 $UBAR  3.0496282-01 $SU  2.8006464+01 $LTLU
     1.8760000+01 $EBAR  7.2318722-01 $SE

   LABEL 2014-T6 PARENT METAL SR
                 1    3.8800000+01    5.2700000+01    1.0200000+01
                 2    3.7600000+01    5.1800000+01    1.0000000+01
                 3    3.6800000+01    5.1000000+01    1.0100000+01
                 4    3.7100000+01    5.1300000+01    1.0400000+01
                 5    3.6600000+01    5.1200000+01    1.0100000+01
     3.7380000+01 $YBAR  8.7864145-01 $SY  3.2327811+01 $LTLY
     5.1600000+01 $UBAR  6.8191759-01 $SU  4.7678974+01 $LTLU
     1.0160000+01 $EBAR  1.5165830-01 $SE

   LABEL 7106-T63 PARENT METAL ANN
                 1    2.1200000+01    3.5000000+01    1.9000000+01
                 2    2.1100000+01    3.5200000+01    1.4900000+01
                 3    2.1100000+01    3.5200000+01    1.3200000+01
                 4    2.0600000+01    3.4800000+01    1.5800000+01
                 5    2.0800000+01    3.5000000+01    1.5500000+01
     2.0960000+01 $YBAR  2.5100506-01 $SY  1.9516721+01 $LTLY
     3.5040000+01 $UBAR  1.6735444-01 $SU  3.4077712+01 $LTLU
     1.5660000+01 $EBAR  2.1208494+00 $SE

   LABEL 7106-T63 PARENT METAL SR
                 1    2.5700000+01    3.9500000+01    1.4400000+01
                 2    2.5400000+01    3.9800000+01    1.3600000+01
                 3    2.5300000+01    3.9200000+01    1.3700000+01
                 4    2.5700000+01    3.9700000+01    1.4200000+01
                 5    2.5400000+01    3.8900000+01    1.4200000+01
     2.5500000+01 $YBAR  1.8708756-01 $SY  2.4424246+01 $LTLY
     3.9420000+01 $UBAR  3.7013136-01 $SU  3.7291745+01 $LTLU
     1.3880000+01 $EBAR  5.7619505-01 $SE
```

TABLE I-3.

UNIAXIAL TENSILE TEST RESULTS ON 2219-T87 AND X7106-T63 ALUMINUM ALLOY WELDMENTS

```
        NUMBER              Y              U              E
  LABEL 2219-T87  TIG 2319 SINGLE
                21    3.0400000+01   3.9700000+01   1.0000000+00
                22    3.0100000+01   3.9500000+01   1.1000000+00
                23    3.1100000+01   3.9800000+01   1.4000000+00
                24    2.9800000+01   3.9200000+01   1.1000000+00
                25    2.8700000+01   3.8700000+01   1.3000000+00
                31    2.9300000+01   4.4900000+01   2.3000000+00
                32    2.6700000+01   4.4000000+01   2.5000000+00
                33    2.7300000+01   4.3000000+01   2.2000000+00
                34    2.7100000+01   4.3700000+01   2.7000000+00
                35    2.6300000+01   4.3300000+01   2.6000000+00
                41    3.1600000+01   4.2800000+01   1.9000000+00
                42    3.3100000+01   4.3100000+01   1.6000000+00
                43    3.0900000+01   4.2000000+01   1.9000000+00
                44    3.1400000+01   4.1900000+01   1.9000000+00
                45    3.1300000+01   4.4000000+01   2.8000000+00
                51    2.9500000+01   3.9100000+01   1.3000000+00
                52    3.0300000+01   4.0000000+01   1.3000000+00
                53    3.1900000+01   4.1200000+01   1.4000000+00
                54    3.0600000+01   3.8900000+01   1.0000000+00
                55    3.0800000+01   4.0900000+01   1.2000000+00
                61    2.8300000+01   3.8400000+01   1.5000000+00
                62    2.9000000+01   3.8900000+01   1.5000000+00
                63    2.9600000+01   3.8500000+01   1.7000000+00
                64    2.9600000+01   3.9700000+01   2.0000000+00
                65    2.9800000+01   4.0600000+01   2.0000000+00
                71    2.9300000+01   4.2900000+01   2.2000000+00
                72    2.9500000+01   4.3300000+01   1.5000000+00
                73    2.8600000+01   4.1900000+01   2.2000000+00
                74    2.8000000+01   4.1300000+01   1.8000000+00
                75    2.9400000+01   4.2900000+01   1.8000000+00
    2.9643333+01 $YBAR  1.5860795+00 $SY  2.4789930+01 $LTLY
    4.1270000+01 $UBAR  1.9715542+00 $SU  3.5237044+01 $LTLU
    1.7566666+00 $EBAR  5.1640896-01 $SE
  LABEL 2219-T87  MIG 2319 SINGLE
                11    2.9900000+01   4.1300000+01   2.0000000+00
                12    2.8000000+01   4.2100000+01   2.9000000+00
                13    2.6600000+01   4.1600000+01   2.9000000+00
                14    2.9100000+01   4.1300000+01   2.6000000+00
                15    2.8600000+01   4.2500000+01   2.4000000+00
                21    3.0300000+01   4.3600000+01   2.7000000+00
                22    2.7900000+01   4.3000000+01   2.6000000+00
                23    2.7400000+01   4.2500000+01   2.4000000+00
                24    2.8700000+01   4.3300000+01   2.7000000+00
                25    2.7500000+01   4.3900000+01   2.8000000+00
                31    3.1100000+01   4.5000000+01   2.6000000+00
                32    2.7600000+01   4.5000000+01   3.0000000+00
                33    2.7800000+01   4.3400000+01   3.2000000+00
                34    2.8500000+01   4.1700000+01   2.7000000+00
                35    2.8800000+01   4.5300000+01   3.0000000+00
    2.8520000+01 $YBAR  1.2007165+00 $SY  2.4293478+01 $LTLY
    4.3033333+01 $UBAR  1.3478431+00 $SU  3.8288926+01 $LTLU
    2.7000000+00 $EBAR  2.9519987-01 $SE
```

TABLE I-3. (Cont'd)

UNIAXIAL TENSILE TEST RESULTS ON 2219-T87 AND X7106-T63 ALUMINUM ALLOY WELDMENTS

```
        NUMBER              Y              U              E
  LABEL 2219-T87  TIG 2319 CROSS
                11    3.1000000+01   4.4800000+01   2.2000000+00
                12    3.0700000+01   4.3800000+01   2.0000000+00
                13    2.9700000+01   4.3700000+01   1.5000000+00
                14    3.0900000+01   4.4300000+01   2.1000000+00
                15    3.1000000+01   4.3300000+01   1.9000000+00
                81    2.9200000+01   3.8300000+01   1.8000000+00
                82    2.9200000+01   3.7900000+01   1.8000000+00
                83    3.0400000+01   4.0500000+01   1.5000000+00
                84    2.9300000+01   4.1000000+01   1.4000000+00
                85    2.9200000+01   4.0000000+01   2.0000000+00
                91    2.9100000+01   4.1700000+01   2.2000000+00
                92    2.8800000+01   4.2200000+01   1.9000000+00
                93    2.9100000+01   3.8800000+01   1.9000000+00
                94    2.8600000+01   4.0900000+01   2.0000000+00
                95    3.1300000+01   4.3100000+01   2.1000000+00
               101    3.1500000+01   4.1000000+01   1.5000000+00
               102    3.0000000+01   3.9900000+01   1.8000000+00
               103    2.9400000+01   4.0800000+01   1.3000000+00
               104    2.9700000+01   4.2800000+01   1.8000000+00
               105    3.0600000+01   4.3200000+01   1.6000000+00
               111    3.5000000+01   4.4300000+01   1.0000000+00
               112    3.0900000+01   4.1100000+01   1.0000000+00
               113    3.0900000+01   4.1000000+01   1.0000000+00
               114    3.1100000+01   4.4300000+01   1.9000000+00
               121    3.2600000+01   4.3500000+01   1.4000000+00
               122    3.0400000+01   4.2400000+01   1.5000000+00
               123    3.0600000+01   4.0200000+01   1.3000000+00
               124    3.2500000+01   4.2000000+01   1.6000000+00
               125    3.1800000+01   4.2000000+01   1.4000000+00
    3.0500000+01 $YBAR  1.3768504+00 $SY  2.6273069+01 $LTLY
    4.1820689+01 $UBAR  1.8663199+00 $SU  3.6091087+01 $LTLU
    1.6689655+00 $EBAR  3.5365791-01 $SE

  LABEL 7106-T63  TIG X5180 SINGLE
                61    3.6500000+01   5.0200000+01   3.1000000+00
                62    3.8900000+01   5.4700000+01   3.4000000+00
                63    4.0500000+01   5.6900000+01   3.5000000+00
                64    4.0100000+01   5.5000000+01   3.4000000+00
                65    4.0200000+01   5.1900000+01   2.2000000+00
                71    3.6400000+01   5.0400000+01   3.1000000+00
                72    3.5200000+01   4.9300000+01   3.2000000+00
                73    3.4800000+01   4.7900000+01   3.2000000+00
                74    3.6000000+01   4.9600000+01   2.6000000+00
                75    3.6000000+01   5.0500000+01   3.2000000+00
                81    3.6200000+01   5.0900000+01   2.6000000+00
                82    3.6000000+01   4.9800000+01   2.5000000+00
                83    3.6800000+01   5.2300000+01   3.1000000+00
                84    3.6400000+01   5.0500000+01   3.1000000+00
                85    3.6100000+01   5.0000000+01   2.5000000+00
    3.7073333+01 $YBAR  1.8740604+00 $SY  3.0476641+01 $LTLY
    5.1326666+01 $UBAR  2.4467134+00 $SU  4.2714235+01 $LTLU
    2.9800000+00 $EBAR  3.9496840-01 $SE
```

TABLE I-4.

UNIAXIAL TENSILE TEST RESULTS ON 2014-T6 ALUMINUM ALLOY WELDMENTS

```
      NUMBER          Y              U              E
 LABEL 2014-T6 TIG 2319 SINGLE
             11   4.1100000+01   4.8600000+01   2.4000000+00
             12   4.1100000+01   5.0200000+01   2.2000000+00
             13   4.1500000+01   5.1100000+01   1.2000000+00
             15   4.1200000+01   4.8500000+01   1.8000000+00
             16   4.0400000+01   4.9000000+01   2.1000000+00
             21   4.1600000+01   5.4300000+01   2.2000000+00
             22   4.1600000+01   5.4300000+01   2.5000000+00
             23   4.2000000+01   5.0200000+01   2.5000000+00
             24   4.2400000+01   5.2400000+01   2.0000000+00
             25   4.1500000+01   5.3500000+01   2.0000000+00
             51   4.0300000+01   4.8700000+01   2.3000000+00
             52   4.2000000+01   4.6100000+01   1.9000000+00
             53   4.4000000+01   4.6000000+01   2.0000000+00
             54   4.0400000+01   4.5600000+01   1.3000000+00
             55   4.1000000+01   4.7800000+01   1.9000000+00
   4.1473333+01 $YBAR   9.2926067-01 $SY   3.8202336+01 $LTLY
   4.9753333+01 $UBAR   2.8992316+00 $SU   3.9548038+01 $LTLU
   2.0200000+00 $EBAR   3.8022550-01 $SE

 LABEL 2014-T6 TIG 4043 SINGLE
             11   4.0300000+01   4.9300000+01   2.5000000+00
             12   4.0000000+01   4.9800000+01   2.5000000+00
             13   3.9600000+01   4.8800000+01   2.3000000+00
             14   3.9400000+01   5.0000000+01   2.0000000+00
             15   4.0000000+01   5.0800000+01   1.7000000+00
             21   3.9100000+01   4.6300000+01   2.1000000+00
             22   3.8300000+01   4.6900000+01   2.4000000+00
             23   3.8700000+01   4.7000000+01   2.6000000+00
             24   3.8500000+01   4.6900000+01   2.1000000+00
             25   3.9200000+01   4.5200000+01   2.1000000+00
             31   3.8500000+01   4.6700000+01   2.0000000+00
             32   3.9000000+01   4.7900000+01   2.5000000+00
             33   3.9400000+01   4.5800000+01   2.4000000+00
             34   3.8000000+01   4.7200000+01   1.9000000+00
             35   3.9500000+01   4.6700000+01   2.3000000+00
   3.9166667+01 $YBAR   6.7259811-01 $SY   3.6799121+01 $LTLY
   4.7686666+01 $UBAR   1.6681419+00 $SU   4.1814807+01 $LTLU

   2.2266667+00 $EBAR   2.6313143-01 $SE
 LABEL 2014-T6 MIG 4043 SINGLF
             11   3.8400000+01   4.4400000+01   2.2000000+00
             12   3.9100000+01   4.5500000+01   2.2000000+00
             13   3.9700000+01   4.6100000+01   2.2000000+00
             14   3.8800000+01   4.5200000+01   2.5000000+00
             15   3.8800000+01   4.4000000+01   2.8000000+00
             21   4.0400000+01   4.4000000+01   1.2000000+00
             22   3.8400000+01   4.3200000+01   1.5000000+00
             23   3.9500000+01   4.2700000+01   1.7000000+00
             24   3.9900000+01   4.5500000+01   1.9000000+00
             25   3.9600000+01   4.4800000+01   1.5000000+00
             31   4.0300000+01   4.4700000+01   1.4000000+00
             32   3.9900000+01   4.5500000+01   1.4000000+00
             33   3.8600000+01   4.4200000+01   1.6000000+00
             34   3.9600000+01   4.3600000+01   1.4000000+00
             35   4.0000000+01   4.6400000+01   1.7000000+00
   3.9400000+01 $YBAR   6.7082299-01 $SY   3.7038703+01 $LTLY
   4.4653333+01 $UBAR   1.0615866+00 $SU   4.0916548+01 $LTLU
   1.8133333+00 $EBAR   4.6731253-01 $SE
```

TABLE I-5.

UNIAXIAL TENSILE TEST RESULTS ON HEAT TREATED 2219-T87 AND X7106-T63 ALUMINUM ALLOY WELDMENTS

```
      NUMBER          Y              U              E

 LABEL 2219-T87 TIG 2319 SINGLE ANN
              1   1.5500000+01   3.0700000+01   1.4000000+01
              2   1.4900000+01   3.0900000+01   1.5400000+01
              3   1.4900000+01   3.0800000+01   1.6200000+01
              4   1.4900000+01   3.0600000+01   1.6200000+01
              5   1.4800000+01   3.0600000+01   1.7800000+01
   1.5000000+01 $YBAR   2.8284595-01 $SY   1.3373636+01 $LTLY
   3.0720000+01 $UBAR   1.3043600-01 $SU   2.9969993+01 $LTLU
   1.5920000+01 $EBAR   1.3827511+00 $SE

 LABEL 2219-T87 TIG 2319 SINGLE SR
              1   4.1500000+01   4.9500000+01   2.4000000+00
              2   3.8900000+01   4.8700000+01   2.5000000+00

              3   3.9000000+01   4.9700000+01   2.2000000+00
              4   4.0200000+01   5.2000000+01   2.5000000+00
              5   3.9500000+01   5.0600000+01   2.1000000+00
   3.9820000+01 $YBAR   1.0709841+00 $SY   3.3661841+01 $LTLY
   5.0100000+01 $UBAR   1.2589675+00 $SU   4.2860937+01 $LTLU
   2.3400000+00 $EBAR   1.8165921-01 $SE

 LABEL 2219-T87 MIG 2319 SINGLE ANN
             51   1.7100000+01   3.3500000+01   1.5400000+01
             52   1.7000000+01   3.3300000+01   1.6000000+01
             53   1.6700000+01   3.2800000+01   1.6400000+01
             54   1.6900000+01   3.2700000+01   1.5500000+01
             55   1.7000000+01   3.3000000+01   1.4100000+01
   1.6940000+01 $YBAR   1.5166616-01 $SY   1.6067919+01 $LTLY
   3.3060000+01 $UBAR   3.3615318-01 $SU   3.1127119+01 $LTLU
   1.5480000+01 $EBAR   8.7005800-01 $SE

 LABEL 2219-T87 MIG 2319 SINGLE SR
              1   4.1800000+01   4.8400000+01   1.9000000+00
              2   4.1000000+01   4.8800000+01   1.9000000+00
              3   4.0200000+01   4.7700000+01   1.9000000+00
              4   4.0600000+01   4.8400000+01   2.0000000+00
              5   4.2500000+01   4.8000000+01   1.7000000+00
   4.1220000+01 $YBAR   9.2844340-01 $SY   3.5881450+01 $LTLY
   4.8260000+01 $UBAR   4.2191117-01 $SU   4.5834011+01 $LTLU
   1.8800000+00 $EBAR   1.0954462-01 $SE

 LABEL 7106-T63 TIG X5180 SINGLF ANN
              1   2.0400000+01   3.4800000+01   1.3200000+01
              2   2.0200000+01   3.5700000+01   1.3600000+01
              3   2.0000000+01   3.4800000+01   1.2600000+01
              4   2.0400000+01   3.4800000+01   1.1600000+01
              5   2.0500000+01   3.4700000+01   1.2200000+01
   2.0300000+01 $YBAR   2.0000229-01 $SY   1.9149987+01 $LTLY
   3.4960000+01 $UBAR   4.1595143-01 $SU   3.2568279+01 $LTLU
   1.2640000+01 $EBAR   7.9246467-01 $SE

 LABEL 7106-T63 TIG X5180 SINGLE SR
              1   2.5200000+01   3.9300000+01   1.1400000+01
              2   2.5100000+01   3.9500000+01   1.1600000+01
              3   2.5200000+01   3.9600000+01   1.2200000+01
              4   2.5200000+01   3.9600000+01   1.1800000+01
              5   2.5500000+01   3.9700000+01   1.1100000+01
   2.5240000+01 $YBAR   1.5164730-01 $SY   2.4368028+01 $LTLY
   3.9540000+01 $UBAR   1.5166616-01 $SU   3.8667920+01 $LTLU
   1.1620000+01 $EBAR   4.1472874-01 $SE
```

TABLE I-6.

UNIAXIAL TENSILE TEST RESULTS ON HEAT TREATED 2014-T6 ALUMINUM ALLOY WELDMENTS

```
          NUMBER              Y                U                 E
LABEL 2014-T6 TIG 2319 SINGLE ANN
                    1   1.3500000+01   2.9500000+01   1.4700000+01
                    2   1.2400000+01   2.9700000+01   1.3600000+01
                    3   1.2400000+01   2.9300000+01   1.4700000+01
                    4   1.2600000+01   2.9800000+01   1.5100000+01
                    5   1.2000000+01   2.9500000+01   1.5600000+01
    1.2580000+01 $YBAR  5.5857070-01 $SY  9.3682185+00 $LTLY
    2.9560000+01 $UBAR  1.9495084-01 $SU  2.8439033+01 $LTLU
    1.4740000+01 $EBAR  7.3688613-01 $SE

LABEL 2014-T6 TIG 2319 SINGLE SR
                    1   3.8000000+01   4.5600000+01   2.2000000+00
                    2   3.7800000+01   4.7800000+01   2.9000000+00
                    3   3.7600000+01   4.6400000+01   2.4000000+00
                    4   3.7800000+01   4.8000000+01   3.1000000+00
                    5   3.7700000+01   4.7300000+01   2.8000000+00
    3.7780000+01 $YBAR  1.4836038-01 $SY  3.6926928+01 $LTLY
    4.7020000+01 $UBAR  1.0059826+00 $SU  4.1235600+01 $LTLU
    2.6800000+00 $EBAR  3.7013518-01 $SE

LABEL 2014-T6 TIG 4043 SINGLE ANN
                    1   1.3800000+01   2.9400000+01   1.4200000+01
                    2   1.2700000+01   2.9400000+01   1.4300000+01
                    3   1.3100000+01   2.9400000+01   1.3600000+01
                    4   1.2700000+01   2.9300000+01   1.3000000+01
                    5   1.2700000+01   2.9600000+01   1.5600000+01
    1.3000000+01 $YBAR  4.7958417-01 $SY  1.0242391+01 $LTLY
    2.9420000+01 $UBAR  1.0956666-01 $SU  2.8789992+01 $LTLU
    1.4140000+01 $EBAR  9.6850435-01 $SE

LABEL 2014-T6 TIG 4043 SINGLE SR
                    1   3.8500000+01   4.7800000+01   3.0000000+00
                    2   3.8100000+01   4.7600000+01   2.8000000+00
                    3   3.7600000+01   4.8000000+01   2.9000000+00
                    4   3.7700000+01   4.6900000+01   2.2000000+00
                    5   3.8000000+01   4.6900000+01   2.3000000+00
    3.7980000+01 $YBAR  3.5637976-01 $SY  3.5930816+01 $LTLY
    4.7440000+01 $UBAR  5.1283573-01 $SU  4.4491194+01 $LTLU
    2.6400000+00 $EBAR  3.6469167-01 $SE

LABEL 2014-T6 MIG 4043 SINGLE ANN
                    1   1.3700000+01   2.9500000+01   1.9000000+01
                    2   1.3000000+01   2.9600000+01   1.8800000+01
                    3   1.2900000+01   2.9800000+01   1.6500000+01
                    4   1.2800000+01   2.9900000+01   1.5600000+01
                    5   1.2600000+01   2.9400000+01   1.3600000+01
    1.3000000+01 $YBAR  4.1832910-01 $SY  1.0594608+01 $LTLY
    2.9640000+01 $UBAR  2.0738104-01 $SU  2.8447559+01 $LTLU
    1.6700000+01 $EBAR  2.2671575+00 $SE

LABEL 2014-T6 MIG 4043 SINGLE SR
                    2   4.2500000+01   4.4600000+01   1.2000000+00
                    3   4.1600000+01   4.4400000+01   1.2000000+00
                    4   4.1300000+01   4.3300000+01   9.0000000-01
                    5   4.2000000+01   4.6000000+01   1.2000000+00
                    6   4.1200000+01   4.3600000+01   8.0000000-01
    4.1720000+01 $YBAR  5.3572620-01 $SY  3.8639574+01 $LTLY
    4.4380000+01 $UBAR  1.0545211+00 $SU  3.8316504+01 $LTLU
    1.0600000+00 $EBAR  1.9493589-01 $SE
```

TABLE I-7.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT DATA, 2014-T6, 2219-T87 AND 7106-T63 WELDMENTS

Panel Description				Bulge Height(a) at Pressure of					Panel Failure	
Material & Process	Type	Welding Procedure	Panel No.	40 psi	80 psi	120 psi	160 psi	200 psi	Pressure, psi	Height, in.
TIG 2219-T87 2319	Single Weld	65A-1	AT1-2	0.69	0.93	1.12	1.29	-	192	1.42
			AT1-3	0.70	(b)	(b)	(b)	-	172	(b)
			AT1-7	0.69	0.93	1.12	1.29	-	192	1.42
			AT1-13	0.62	0.83	1.00	-	-	136	1.05
	Cross Weld	65A-1	AT1-1	0.56	0.79	0.96	1.14	-	163	1.15
			AT1-8	0.82	1.02	1.21	-	-	156	1.35
			AT1-9	0.65	0.89	1.10	-	-	158	1.26
MIG 2219-T87 2319	Single Weld	65A-26	AM1-1	(c)	-	-	-	-	148	-
			AM1-2	(c)	-	-	-	-	174	-
			AM1-3	(c)	-	-	-	-	200	-
TIG 2014-T6 2319	Single Weld	65A-24	BT1-1	(c)	-	-	-	-	218	-
			BT1-2	0.67	0.90	1.06	1.20	-	178	1.27
			BT1-5	(c)	-	-	-	-	200	-
TIG 2014-T6 4043	Single Weld	65A-25	BT2-1	(c)	-	-	-	-	172	-
			BT2-2	(c)	-	-	-	-	224	-
			BT2-3	(c)	-	-	-	-	170	-
MIG 2014-T6 4043	Single Weld	65A-27	BM2-1	(c)	-	-	-	-	152	-
			BM2-2	(c)	-	-	-	-	160	-
			BM2-3	(c)	-	-	-	-	165	-
TIG 7106-T63 X5180	Single Weld	65A-23	CT3-6	0.64	0.90	1.10	1.25	1.41	225	1.52
			CT3-7	0.78	1.10	1.32	1.50	1.68	240	1.95
			CT3-8	0.65	0.90	1.08	1.22	1.40	245	1.58

(a) Bulge height in inches at applied pressure indicated.
(b) Deflectometer inoperative.
(c) Data not obtained.

TABLE I-8.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT DATA AS RECEIVED AND HEAT TREATED PARENT METAL

Panel Description			Bulge Height(a) at Pressure of													Panel Failure	
Material & Process	Heat Treatment	Panel No.	40 psi	80 psi	120 psi	160 psi	200 psi	300 psi	400 psi	500 psi	600 psi	700 psi	800 psi	900 psi	1000 psi	Pressure, psi	Height, in.
2219-T87 Parent Metal	As Received	A-26	0.65	0.78	0.91	1.04	1.18	1.48	1.78	2.10	2.78	-	-	-	-	(b)	(b)
		A-27	0.59	0.80	1.00	1.15	1.27	1.62	1.97	2.24	2.60	2.90	3.21	3.60	4.18	1090	4.75
		A-28	0.64	0.85	1.02	1.17	1.32	1.66	2.00	2.35	2.60	2.92	3.25	3.65	4.40	1000	4.40
	Annealed(a)	A-31	0.70	1.18	1.52	1.83	2.04	2.80	3.68	-	-	-	-	-	-	464	4.35
	Stress Relieved(b)	A-30	0.65	0.85	1.03	1.19	1.41	1.82	2.30	2.68	3.05	3.84	-	-	-	780	5.02
2014-T6 Parent Metal	As Received	B-8	0.63	0.80	0.93	1.07	1.20	1.47	1.73	2.03	2.35	2.64	2.94	3.30	3.70	1050	4.00
		B-9	0.67	0.82	1.00	1.13	1.24	1.53	1.83	2.08	2.40	2.67	2.96	3.35	3.80	1040	4.00
		B-10	0.57	0.78	0.92	1.07	1.18	1.45	1.72	2.00	2.29	2.60	2.94	3.20	3.72	1060	4.00
	Annealed	B-11	0.58	1.04	1.52	1.84	2.05	2.82	3.56	4.72	-	-	-	-	-	560	6.32
	Stress Relieved	B-7	0.67	0.89	1.08	1.31	1.50	1.98	2.34	2.82	3.34	-	-	-	-	635	3.75
7106-T63 Parent Metal	As Received	C-2	0.65	0.80	1.00	1.17	1.27	1.60	1.92	2.24	2.54	2.86	3.20	3.60	4.16	1010	4.25
		C-3	0.60	0.80	0.95	1.08	1.20	1.50	1.87	2.16	2.48	2.80	3.07	3.42	3.90	1050	4.25
		C-5	0.52	0.75	0.88	1.04	1.18	1.47	1.75	2.11	2.44	2.75	3.07	3.42	3.92	1050	4.30
	Annealed	C-4	0.58	0.96	1.35	1.65	1.92	2.58	3.18	3.78	4.92	-	-	-	-	610	5.10
	Stress Relieved	C-1	0.67	1.00	1.39	1.63	1.90	2.46	3.02	3.80	-	-	-	-	-	576	4.95

(a) Bulge height in inches.
(b) Failed in bolt holes.

TABLE I-9.

1:1 HYDRAULIC BULGE TEST PRESSURE - BULGE HEIGHT DATA HEAT TREATED WELDMENTS

Panel Description				Bulge Height(a) at Pressure of							Panel Failure	
Material & Process	Heat Treatment	Welding Procedure	Panel No.	40 psi	80 psi	120 psi	160 psi	200 psi	300 psi	400 psi	Pressure, psi	Height, in.
TIG 2219-T87 2319	Annealed(a)	65A-1	AT1-20	0.79	1.25	1.61	1.89	2.17	2.90	3.70	416	3.86
	Stress Relieved(b)	65A-1	AT1-18	0.69	0.91	1.15	1.31	1.58	-	-	275	1.90
MIG 2219-T87 2319	Annealed	65A-26	AM1-5	0.76	1.20	1.55	1.85	2.15	2.85	-	360	3.30
	Stress Relieved	65A-26	AM1-4	0.70	0.99	1.20	1.42	1.62	-	-	275	1.99
TIG 2014-T6 2319	Annealed	65A-24	BT1-4	0.97	1.36	1.75	2.02	2.33	2.58	3.02	425	4.12
	Stress Relieved	65A-24	BT1-3	0.70	0.97	1.20	1.41	1.63	2.11	-	320	2.19
TIG 2014-T6 4043	Annealed	65A-25	BT2-5	0.92	1.35	1.69	2.00	2.27	3.02	3.81	420	4.05
	Stress Relieved	65A-25	BT2-4	0.60	0.78	1.02	1.24	1.51	-	-	265	1.67
MIG 2014-T6 4043	Annealed	65A-27	BM2-5	0.92	1.39	1.72	-	-	-	-	144	2.08
	Stress Relieved	65A-27	BM2-4	0.65	0.90	1.14	-	-	-	-	144	1.29
TIG 7106-T63 X5180	Annealed	65A-23	CT3-5	0.72	1.10	1.50	1.81	2.09	2.71	3.32	485	3.91
	Stress Relieved	65A-23	CT3-9	0.57	0.82	1.14	1.37	1.59	2.09	2.52	496	2.52

(a) Bulge height in inches.

APPENDIX J

PHASE III TENSILE TEST DATA
(CONTRACT NAS8-20160)

PHASE III TENSILE TEST DATA
(CONTRACT NAS8-20160)

The results of the individual uniaxial tensile tests conducted in the study of the weldability of X7106-T63 aluminum alloy (Phase III, Contract NAS8-20160) are listed in Tables J-1 through J-22. The computed mean value, standard deviation and lower tolerance limit for each property are also included in the tables. These computations were carried out on a GE 225 digital computer in accordance with the procedures described in Appendix K. Table J-1 through J-22 are reproduced from the computer print-out sheets and the letter symbols appearing in the tables are as follows:

Y	0.2% Offset Yield Strength, ksi
$YBAR	Average Value of Yield Strength, ksi
$SY	Standard Deviation of Yield Strength, ksi
$LTLY	Lower Tolerance Limit of Yield Strength, ksi
U	Ultimate Tensile Strength, ksi
$UBAR	Average Value of Ultimate Strength, ksi
$SU	Standard Deviation of Ultimate Strength, ksi
$LTLU	Lower Tolerance Limit of Ultimate Strength, ksi
E	Elongation in Two Inches, %
$EBAR	Average Value of Elongation
$SE	Standard Deviation of Elongation, %

The floating decimal point system was used in this computation and all values in the tables are given in powers of ten. For example:

5.2500000 + 01 = 52.500000

7.0454965 - 01 = 0.70454965

TABLE J-1.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT3-1, 0.187-inch TIG/X5180, Sq Butt.

```
        NUMBER              Y                U                 E
LABEL CT3-1 TIG-7106,5180,0.187,1 DAY
                 1   2.7000000+01   4.2100000+01   4.6000000+00
                 7   2.8300000+01   4.1100000+01   3.7000000+00
                13   3.0400000+01   4.4000000+01   3.3000000+00
                19   2.9600000+01   4.3600000+01   3.7000000+00
                25   2.9700000+01   4.3000000+01   3.4000000+00
                31   3.0700000+01   4.5500000+01   4.0000000+00
   2.9283333+01 $YBAR  1.3934399+00 $SY  2.2232527+01 $LTLY
   4.3216667+01 $UBAR  1.5328615+00 $SU  3.5460388+01 $LTLU
   3.7833333+00 $EBAR  4.7081505-01 $SE

LABEL CT3-1 TIG-7106,5180,0.187,3 DAYS
                 2   3.2000000+01   4.7600000+01   3.9000000+00
                 8   3.2300000+01   4.6500000+01   2.7000000+00
                14   3.2100000+01   4.5700000+01   3.1000000+00
                20   3.2200000+01   4.6700000+01   3.0000000+00
                26   3.3100000+01   4.7900000+01   3.1000000+00
                32   3.2900000+01   4.8700000+01   3.9000000+00
   3.2433333+01 $YBAR  4.5460762-01 $SY  3.0133019+01 $LTLY
   4.7183333+01 $UBAR  1.0852150+00 $SU  4.1692149+01 $LTLU
   3.2833333+00 $EBAR  4.9966653-01 $SE

LABEL CT3-1 TIG-7106,5180,0.187,1 WEEK
                 3   3.3100000+01   4.8100000+01   4.0000000+00
                 9   3.1400000+01   4.9200000+01   3.1000000+00
                15   3.3000000+01   4.6200000+01   3.2000000+00
                21   3.3900000+01   4.9000000+01   3.8000000+00
                27   3.2800000+01   4.8400000+01   3.4000000+00
                33   3.4600000+01   4.9000000+01   2.4000000+00
   3.3133333+01 $YBAR  1.0838249+00 $SY  2.7649179+01 $LTLY
   4.8316667+01 $UBAR  1.1178866+00 $SU  4.2660161+01 $LTLU
   3.3166666+00 $EBAR  5.6715674-01 $SE

LABEL CT3-1 TIG-7106,5180,0.187,2 WEEKS
                 4              0   5.2600000+01   4.1000000+00
                10   3.7300000+01   5.1600000+01   3.3000000+00
                16   3.4600000+01   4.8000000+01   4.5000000+00
                22   3.5100000+01   5.0200000+01   3.9000000+00
                28   3.5800000+01   5.1900000+01   2.8000000+00
                34   3.7000000+01   5.2100000+01   2.7000000+00
   3.5960000+01 $YBAR  1.1717529+00 $SY  2.9222421+01 $LTLY
   5.1066667+01 $UBAR  1.7060683+00 $SU  4.2433961+01 $LTLU
   3.5500000+00 $EBAR  7.3143697-01 $SE

LABEL CT3-1,TIG-7106,5180,.187,5 WEEKS
                 5   3.8900000+01   5.4300000+01   3.6000000+00
                11   3.8000000+01   5.2700000+01   2.8000000+00
                17   3.6800000+01   5.1600000+01   2.7000000+00
                23   3.8500000+01   5.4800000+01   3.0000000+00
                29   3.9000000+01   5.5100000+01   3.2000000+00
                35   3.9100000+01   5.5400000+01   3.6000000+00
   3.8383333+01 $YBAR  8.7502790-01 $SY  3.3955692+01 $LTLY
   5.3983333+01 $UBAR  1.5065490+00 $SU  4.6360195+01 $LTLU
   3.1500000+00 $EBAR  3.8858727-01 $SE

LABEL CT3-1, TIG-7106, 5180, .187, 12 WEEKS
                 6   3.9100000+01   5.4500000+01   3.2000000+00
                12   4.0500000+01   5.6600000+01   3.0000000+00
                18   3.9800000+01   5.4300000+01   2.7000000+00
                24   3.9500000+01   5.5100000+01   3.4000000+00
                30   4.1600000+01   5.6800000+01   3.5000000+00
                36   4.1200000+01   5.6600000+01   3.1000000+00
   4.0283333+01 $YBAR  9.8675308-01 $SY  3.5290363+01 $LTLY
   5.5650000+01 $UBAR  1.1467462+00 $SU  4.9847464+01 $LTLU
   3.1500000+00 $EBAR  2.5509736-01 $SE
```

TABLE J-2.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT3-1, 0.187-inch TIG/5356, Sq Butt.

```
        NUMBER              Y                U                 E
LABEL CT4-1TIG-7106,5356,0.187,1 DAY
                 1   2.7900000+01   4.3000000+01   4.6000000+00
                 7   2.9200000+01   4.2100000+01   4.0000000+00
                13   3.0100000+01   4.3300000+01   3.7000000+00
                19   2.9300000+01   4.3300000+01   2.5000000+00
                25   2.9000000+01   4.2700000+01   3.5000000+00
                31   2.9000000+01   4.4500000+01   4.2000000+00
   2.9083333+01 $YBAR  7.0828618-01 $SY  2.5499405+01 $LTLY
   4.3150000+01 $UBAR  7.9938712-01 $SU  3.9105181+01 $LTLU
   3.7500000+00 $EBAR  7.2318746-01 $SE

LABEL CT4-1,TIG,7106,5356,0.187,3 DAY
                 2   3.1700000+01   4.7300000+01   3.8000000+00
                 8   3.1800000+01   4.6400000+01   2.6000000+00
                14   3.1500000+01   4.6000000+01   3.8000000+00
                20   3.1600000+01   4.5600000+01   2.6000000+00
                26   3.1500000+01   4.5700000+01   3.3000000+00
                32   3.1900000+01   4.8200000+01   3.4000000+00
   3.1666667+01 $YBAR  1.6330741-01 $SY  3.0840331+01 $LTLY
   4.6533333+01 $UBAR  1.0230826+00 $SU  4.1356535+01 $LTLU
   3.2500000+00 $EBAR  5.4313914-01 $SE

LABEL CT4-1,TIG,7106,5356,0.187,1 WEEK
                 3   3.2600000+01   4.7500000+01   3.2000000+00
                 9   3.3600000+01   4.7600000+01   3.8000000+00
                15   3.0900000+01   4.5700000+01   3.4000000+00
                21   3.2800000+01   4.6200000+01   3.2000000+00
                27   3.3100000+01   4.7300000+01   3.3000000+00
                33   3.3600000+01   4.8900000+01   3.6000000+00
   3.2766667+01 $YBAR  1.0013373+00 $SY  2.7699900+01 $LTLY
   4.7200000+01 $UBAR  1.1313757+00 $SU  4.1475239+01 $LTLU
   3.4166667+00 $EBAR  2.4013888-01 $SE

LABEL CT4-1,TIG-7106,5356,0.187,2 WEEKS
                 4   3.4500000+01   5.0300000+01   3.1000000+00
                10   3.4400000+01   4.8700000+01   2.8000000+00
                16              0   4.9900000+01   3.6000000+00
                22   3.3400000+01   4.7200000+01   3.4000000+00
                28   3.5400000+01   4.9900000+01   3.1000000+00
                34   3.4000000+01   4.9800000+01   3.0000000+00
   3.4340000+01 $YBAR  7.3348881-01 $SY  3.0122439+01 $LTLY
   4.9300000+01 $UBAR  1.1610358+00 $SU  4.3425159+01 $LTLU
   3.1666667+00 $EBAR  2.8751810-01 $SE

LABEL CT4-1,TIG-7106,5356,0.187,5 WEEKS
                 5   3.5900000+01   5.1200000+01   2.8000000+00
                11   3.6800000+01   4.9200000+01   3.3000000+00
                17   3.6400000+01   5.2100000+01   3.7000000+00
                23   3.7100000+01   5.1600000+01   3.8000000+00
                29   3.6800000+01   5.1800000+01   3.4000000+00
                35   3.6300000+01   5.2200000+01   3.4000000+00
   3.6550000+01 $YBAR  4.3244499-01 $SY  3.4361828+01 $LTLY
   5.1350000+01 $UBAR  1.1131044+00 $SU  4.5717692+01 $LTLU
   3.4000000+00 $EBAR  3.5213644-01 $SE

LABEL CT4-1, TIG-7106, 5356, 0.187, 12 WEEKS
                 6   3.8900000+01   5.3600000+01   3.2000000+00
                12   3.7500000+01   5.0900000+01   2.5000000+00
                18   3.6800000+01   5.2000000+01   4.3000000+00
                24   3.7300000+01   5.2800000+01   3.7000000+00
                30   3.8900000+01   5.4100000+01   3.7000000+00
                36   3.8400000+01   5.3500000+01   2.8000000+00
   3.7933333+01 $YBAR  7.1360165-01 $SY  3.4310509+01 $LTLY
   5.2816667+01 $UBAR  1.1889793+00 $SU  4.6800431+01 $LTLU
   3.3666667+00 $EBAR  6.6231920-01 $SE
```

TABLE J-3.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT5-5, 0.187-inch TIG/5556, Sq Butt.

```
              NUMBER          Y               U               E
LABEL CT5-5,TIG-7106,5556,0.187,1 DAY
                    1   2.8100000+01    4.1100000+01    4.2000000+00
                    7   3.0100000+01    4.3400000+01    3.5000000+00
                   13   2.9000000+01    4.2600000+01    2.8000000+00
                   19   3.0100000+01    4.3300000+01    3.3000000+00
                   25   3.0200000+01    4.3900000+01    3.1000000+00
                   31   3.0600000+01    4.5800000+01    4.5000000+00
  2.9683333+01 $YBAR  9.4110148-01 $SY  2.4921360+01 $LTLY
  4.3350000+01 $UBAR  1.5449937+00 $SU  3.5532332+01 $LTLU
  3.5666667+00 $EBAR  6.5625200-01 $SE

LABEL CT5-5TIG-7106,5556,0.187,3 DAY
                    2   3.1500000+01    4.5000000+01    2.8000000+00
                    8   3.2800000+01    4.6100000+01    3.0000000+00
                   14   3.3900000+01    4.6700000+01    2.7000000+00
                   20   3.3400000+01    4.9100000+01    3.3000000+00
                   26   3.2700000+01    4.7300000+01    2.2000000+00
                   32   3.6100000+01    4.9900000+01    3.6000000+00
  3.3400000+01 $YBAR  1.5491953+00 $SY  2.5561072+01 $LTLY
  4.7350000+01 $UBAR  1.8479709+00 $SU  3.7999267+01 $LTLU
  2.9333333+00 $EBAR  4.8853528-01 $SE

LABEL CT5-5,TIG-7106,5556,0.187,1 WEEK
                    3   3.2300000+01    4.6700000+01    3.3000000+00
                    9   3.2000000+01    4.5200000+01    1.6000000+00
                   15   3.4400000+01    4.6200000+01    2.5000000+00
                   21   3.4100000+01    4.7800000+01    2.5000000+00
                   27   3.3600000+01    4.8600000+01    3.8000000+00
                   33              0    4.9700000+01    3.6000000+00
  3.3280000+01 $YBAR  1.0756436+00 $SY  2.7095049+01 $LTLY
  4.7366666+01 $UBAR  1.6524776+00 $SU  3.9005130+01 $LTLU
  2.8833333+00 $EBAR  8.3286657-01 $SE

LABEL CT5-5,TIG-7106,5556,0.187,2 WEEKS
                    4   3.4600000+01    5.0300000+01    3.6000000+00
                   10   3.4700000+01    4.8700000+01    2.8000000+00
                   16   3.6600000+01    4.9000000+01    2.5000000+00
                   22   3.6300000+01    5.1400000+01    3.0000000+00
                   28   3.7900000+01    5.3600000+01    3.0000000+00
                   34   3.8000000+01    5.2600000+01    3.3000000+00
  3.6350000+01 $YBAR  1.4815547+00 $SY  2.8853333+01 $LTLY
  5.0933333+01 $UBAR  1.9612985+00 $SU  4.1009163+01 $LTLU
  3.0333333+00 $EBAR  3.8297085-01 $SE

LABEL CT5-5,TIG-7106,5556,0.187,5 WEEKS
                    5   3.6700000+01    5.0600000+01    3.4000000+00
                   11   3.7000000+01    5.0300000+01    3.3000000+00
                   17   3.8100000+01    5.1600000+01    3.2000000+00
                   23   3.7900000+01    5.2200000+01    2.7000000+00
                   29              0    5.3500000+01    3.5000000+00
                   39   3.7500000+01    5.1400000+01    3.2000000+00
                   35   3.7500000+01    5.3300000+01    3.5000000+00
  3.7450000+01 $YBAR  5.2820820-01 $SY  3.4777266+01 $LTLY
  5.1842857+01 $UBAR  1.2367461+00 $SU  4.6104355+01 $LTLU
  3.2571428+00 $EBAR  2.7602622-01 $SE

LABEL CT5-5, TIG-7106, 5556, 0.187, 12 WEEKS
                    6   3.7100000+01    5.3800000+01    3.5000000+00
                   12   3.8600000+01    5.1100000+01    2.9000000+00
                   18   4.1300000+01    5.4900000+01    2.6000000+00
                   24   3.9300000+01    5.3300000+01    2.8000000+00
                   30   3.6300000+01    5.4700000+01    3.3000000+00
                   36   3.8600000+01    5.3300000+01              30
  3.8866667+01 $YBAR  1.3923620+00 $SY  3.1821315+01 $LTLY
  5.3516667+01 $UBAR  1.3658922+00 $SU  4.6605252+01 $LTLU
  7.5166667+00 $EBAR  [illegible]
```

TABLE J-4.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM3-1, 0.187-inch MIG/X5180, Sq Butt.

```
              NUMBER          Y               U               E
LABEL CM3-1,MIG-7106,5180,0.187,1 DAY
                    1   3.0800000+01    4.6100000+01    3.7000000+00
                    7   3.1300000+01    4.5100000+01    3.7000000+00
                   13   3.1400000+01    4.6800000+01    3.7000000+00
                   19   3.0100000+01    4.7800000+01    4.6000000+00
                   25   3.0900000+01    4.6300000+01    4.3000000+00
                   31   3.0700000+01    4.7500000+01    4.8000000+00
  3.0866667+01 $YBAR  4.6761581-01 $SY  2.8500531+01 $LTLY
  4.6600000+01 $UBAR  9.8793379-01 $SU  4.1601055+01 $LTLU
  4.1333333+00 $EBAR  5.0066627-01 $SE

LABEL CM3-1,MIG-7106,5180,0.187,5 DAYS
                    2   3.3600000+01    4.9500000+01    3.7000000+00
                    8   3.3700000+01    4.7800000+01    3.3000000+00
                   14   3.3800000+01    4.8900000+01    8.4000000+00
                   20   3.3600000+01    5.1300000+01    5.4000000+00
                   26   3.3500000+01    4.8300000+01    2.9000000+00
                   32   3.3400000+01    5.0200000+01    4.5000000+00
  3.3600000+01 $YBAR  1.4143646-01 $SY  3.2884331+01 $LTLY
  4.9333333+01 $UBAR  1.2847869+00 $SU  4.2832311+01 $LTLU
  4.7000000+00 $EBAR  2.0208909+00 $SE

LABEL CM3-1,MIG-7106,5180,0.187,9 DAYS
                    3   3.6100000+01    5.0600000+01    3.3000000+00
                    9   3.6300000+01    5.0400000+01    3.4000000+00
                   15   3.7400000+01    5.1400000+01    3.2000000+00
                   21   3.5800000+01    5.1300000+01    3.3000000+00
                   27   3.6400000+01    5.1600000+01    3.2000000+00
                   33   3.6400000+01    5.2300000+01    4.5000000+00
  3.6400000+01 $YBAR  5.4037713-01 $SY  3.3665691+01 $LTLY
  5.1266667+01 $UBAR  6.9186293-01 $SU  4.7765840+01 $LTLU
  3.4833333+00 $EBAR  5.0365339-01 $SE

LABEL CM3-1,MIG-7106,5180,0.187,2 WEEKS
                    4   3.7300000+01    5.4000000+01    4.2000000+00
                   10   3.7200000+01    5.1000000+01    3.3000000+00
                   16   3.7900000+01    5.2500000+01    4.0000000+00
                   22   3.6400000+01    5.0200000+01    3.2000000+00
                   28   3.6900000+01    5.2200000+01    3.7000000+00
                   34   3.7100000+01    5.3200000+01    3.9000000+00
  3.7133333+01 $YBAR  4.9261514-01 $SY  3.4640701+01 $LTLY
  5.2183333+01 $UBAR  1.3977434+00 $SU  4.5110752+01 $LTLU
  3.7166667+00 $EBAR  3.9707276-01 $SE

LABEL CM3-1,MIG-7106,5180,0.187,5 WEEKS
                    5   3.9000000+01    5.5100000+01    3.2000000+00
                   11   3.8700000+01    5.2300000+01    3.6000000+00
                   17   3.7600000+01    5.4000000+01    3.3000000+00
                   23   3.8400000+01    5.3500000+01    3.2000000+00
                   29   3.8500000+01    5.5100000+01    4.2000000+00
                   35   3.9000000+01    5.4700000+01    3.3000000+00
  3.8566667+01 $YBAR  4.5018578-01 $SY  3.6268727+01 $LTLY
  5.4116666+01 $UBAR  1.0925607+00 $SU  4.8568309+01 $LTLU
  3.4666667+00 $EBAR  3.6815792-01 $SE

LABEL CM3-1, MIG-7106, 5180, 0.187, 12 WEEKS
                    6   4.0200000+01    5.6200000+01    3.7000000+00
                   12   4.1200000+01    5.5900000+01    4.0000000+00
                   18   4.0600000+01    5.8100000+01    4.5000000+00
                   24   4.0500000+01    5.7200000+01    4.0000000+00
                   30   4.0200000+01    5.7200000+01    4.2000000+00
                   36   3.9400000+01    5.6200000+01    3.5000000+00
  4.0350000+01 $YBAR  5.9245335-01 $SY  3.7352186+01 $LTLY
  5.6800000+01 $UBAR  8.4143925-01 $SU  5.2542317+01 $LTLU
  3.9833333+00 $EBAR  3.5449494-01 $SE
```

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM4-1, 0.187-inch MIG/5356, Sq Butt.

```
          NUMBER            Y              U                E
LABEL CM4-1,MIG-7106,5356,0.187,1 DAY
               1   3.0200000+01    4.4300000+01     3.0000000+00
               7   3.0800000+01    4.5400000+01     4.2000000+00
              13   3.1900000+01    4.7100000+01     4.3000000+00
              19   3.1200000+01    4.7100000+01     3.9000000+00
              25   3.1700000+01    4.7700000+01     5.3000000+00
              31   3.1100000+01    4.6900000+01     4.1000000+00
   3.1150000+01 $YBAR  6.1563045-01 $SY  2.8034910+01 $LTLY
   4.6416667+01 $UBAR  1.2906099+00 $SU  3.9886181+01 $LTLU
   4.1333333+00 $EBAR  7.3936913-01 $SE

LABEL CM4-1,MIG-7106,5356,0.187,5 DAYS
               2   3.3000000+01    4.6900000+01     3.8000000+00
               8   3.2700000+01    4.5900000+01     2.8000000+00
              14   3.3200000+01    4.8100000+01     5.2000000+00
              20   3.3200000+01    4.8700000+01     5.0000000+00
              26   3.3200000+01    4.8200000+01     3.9000000+00
              32   3.3100000+01    4.9400000+01     4.6000000+00
   3.3066666+01 $YBAR  1.9665942-01 $SY  3.2071570+01 $LTLY
   4.7866667+01 $UBAR  1.2659674+00 $SU  4.1460872+01 $LTLU
   4.2166666+00 $EBAR  8.9535855-01 $SE

LABEL CM4-1,MIG-7106,5356,0.187,9 DAYS
               3              0    4.8400000+01     2.4000000+00
              39   3.3300000+01    5.0200000+01     3.5000000+00
               9   3.5900000+01    4.9800000+01     2.9000000+00
              15   3.5100000+01    5.1200000+01     3.9000000+00
              21   3.3300000+01    5.2100000+01     3.9000000+00
              27   3.4200000+01    5.0600000+01     3.8000000+00
              33              0    5.1100000+01     4.4000000+00
              0.   3.5600000+01    4.9700000+01     3.7000000+00
   3.4566666+01 $YBAR  1.1378417+00 $SY  2.8809187+01 $LTLY
   5.0387500+01 $UBAR  1.1306630+00 $SU  4.5469116+01 $LTLU
   3.5625000+00 $EBAR  6.3231433-01 $SE

LABEL CM4-1,MIG-7106,5356,0.187,2 WEEKS
               4   3.5400000+01    5.0300000+01     3.3000000+00
              10   3.5700000+01    5.1200000+01     4.0000000+00
              16   3.6800000+01    5.1100000+01     3.5000000+00
              22   3.5300000+01    5.4200000+01     4.9000000+00
              28   3.5600000+01    5.2100000+01     4.2000000+00
              34   3.5100000+01    5.1100000+01     3.5000000+00
   3.5650000+01 $YBAR  6.0250028-01 $SY  3.2601348+01 $LTLY
   5.1666667+01 $UBAR  1.3662653+00 $SU  4.4753364+01 $LTLU
   3.9000000+00 $EBAR  5.9665739-01 $SE

LABEL CM4-1,MIG-7106,5356,0.187,5 WEEKS
               5   3.6600000+01    5.1800000+01     2.8000000+00
              11   3.7400000+01    5.1800000+01     2.9000000+00
              17   3.6100000+01    5.2200000+01     3.2000000+00
              23   3.7200000+01    5.3500000+01     3.7000000+00
              29   3.7600000+01    5.3400000+01     3.7000000+00
              35   3.7200000+01    5.4000000+01     4.0000000+00
   3.7016667+01 $YBAR  5.6006962-01 $SY  3.4182714+01 $LTLY
   5.2783333+01 $UBAR  9.6419038-01 $SU  4.7904530+01 $LTLU
   3.3833333+00 $EBAR  4.8751067-01 $SE

LABEL CM4-1, MIG-7106, 5356, 0.187, 12 WEEKS
               6   3.8400000+01    5.2600000+01     3.0000000+00
              12   3.9900000+01    5.3900000+01     3.0000000+00
              18   3.9000000+01    5.3800000+01     3.5000000+00
              24   3.9500000+01    5.5600000+01     4.2000000+00
              30   4.0200000+01    5.5600000+01     3.7000000+00
              36   3.9000000+01    5.7400000+01     5.0000000+00
   3.9333333+01 $YBAR  6.6232309-01 $SY  3.5981976+01 $LTLY
   5.4816666+01 $UBAR  1.1359742+00 $SU  4.6143957+01 $LTLU
   3.7333333+00 $EBAR  7.6854845-01 $SE
```

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM5-2, 0.187-inch MIG/5556, Sq Butt.

```
          NUMBER            Y              U                E
LABEL CM5-2,MIG-7106,5556,0.187,1 DAY
               1   3.1800000+01    4.6200000+01     4.9000000+00
               7   3.1700000+01    4.5400000+01     3.8000000+00
              13   3.1500000+01    4.5900000+01     4.4000000+00
              19   3.1300000+01    4.5300000+01     4.1000000+00
              25   2.9400000+01    4.5000000+01     4.4000000+00
              31   3.1800000+01    4.5400000+01     4.4000000+00
   3.1250000+01 $YBAR  9.2682727-01 $SY  2.6560254+01 $LTLY
   4.5533333+01 $UBAR  4.3665516-01 $SU  4.3323858+01 $LTLU
   4.3333333+00 $EBAR  3.6696972-01 $SE

LABEL CM5-2,MIG-7106,5556,0.187,5 DAYS
               2   3.4100000+01    4.7300000+01     3.5000000+00
               8   3.3200000+01    4.8600000+01     4.0000000+00
              14   3.3900000+01    4.8200000+01     4.1000000+00
              20   3.2800000+01    5.1300000+01     5.3000000+00
              26   3.3400000+01    4.7400000+01     4.3000000+00
              32   3.3500000+01    4.8000000+01     3.3000000+00
   3.3483333+01 $YBAR  4.7082224-01 $SY  3.1100973+01 $LTLY
   4.8466666+01 $UBAR  1.4719671+00 $SU  4.1018513+01 $LTLU
   4.0833333+00 $EBAR  7.0545495-01 $SE

LABEL CM5-2,MIG-7106,5556,0.187,9 DAYS
               3   3.5400000+01    5.1100000+01     2.9000000+00
               9   3.6800000+01    5.0000000+01     2.9000000+00
              15   3.9700000+01    4.9600000+01     3.4000000+00
              21   3.4100000+01    5.2300000+01     5.4000000+00
              27   3.5300000+01    5.1900000+01     4.2000000+00
              33   3.5100000+01    4.9800000+01     3.3000000+00
   3.6066666+01 $YBAR  1.9785548+00 $SY  2.6055179+01 $LTLY
   5.0783333+01 $UBAR  1.1513727+00 $SU  4.4957387+01 $LTLU
   3.6833333+00 $EBAR  9.6626433-01 $SE

LABEL CM5-2,MIG-7106,5556,0.187,2 WEEKS
               4   3.6200000+01    5.2000000+01     4.3000000+00
              10   3.6700000+01    5.0600000+01     4.0000000+00
              16   3.6300000+01    5.1300000+01     3.6000000+00
              22   3.6100000+01    5.1300000+01     3.7000000+00
              28   3.6300000+01    5.2300000+01     3.9000000+00
              34   3.6300000+01    5.0600000+01     3.7000000+00
   3.6316666+01 $YBAR  2.0414408-01 $SY  3.5283697+01 $LTLY
   5.1350000+01 $UBAR  7.0074249-01 $SU  4.7804243+01 $LTLU
   3.8666667+00 $EBAR  2.5819904-01 $SE

LABEL CM5-2,MIG-7106,5556,0.187,5WEEKS
               5   3.7500000+01    5.3700000+01     4.0000000+00
              11   3.6300000+01    5.2500000+01     4.1000000+00
              17   3.6900000+01    5.2300000+01     3.6000000+00
              23   3.6900000+01    5.2300000+01     6.6000000+00
              29   3.7000000+01    5.1400000+01     9.0000000+00
              35   3.7000000+01    5.2000000+01     3.9000000+00
   3.7266667+01 $YBAR  5.5577345-01 $SY  3.4464573+01 $LTLY
   5.2366666+01 $UBAR  7.5807824-01 $SU  4.8530791+01 $LTLU
   5.5333333+00 $EBAR  2.3390287+00 $SE

LABEL CM5-2, MIG-7106, 5556, 0.187, 12 WEEKS
               6   3.9500000+01    5.5100000+01     3.0000000+00
              12   4.0300000+01    5.5000000+01     3.7000000+00
              18   4.0000000+01    5.4000000+01     3.7000000+00
              24   3.9100000+01    5.5000000+01     4.3000000+00
              30   3.9800000+01    5.6200000+01     4.2000000+00
              36   4.0500000+01    5.3100000+01     3.2000000+00
   3.9866667+01 $YBAR  5.1640566-01 $SY  3.7253654+01 $LTLY
   5.4733333+01 $UBAR  1.0614540+00 $SU  4.9362376+01 $LTLU
   3.6833333+00 $EBAR  5.1929449-01 $SE
```

TABLE J-7.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT3-2, 0.50-inch TIG/X5180, Sq Butt.

```
          NUMBER         Y               U                E
 LABEL CT3-2,TIG-7106,5180,0.50,1 DAY
               1   2.7100000+01   4.5500000+01   1.0200000+01
               7   2.6800000+01   4.5600000+01   1.0000000+01
              13   2.6700000+01   4.5900000+01   1.0700000+01
              19   2.6700000+01   4.5900000+01   1.0900000+01
              26              0   4.6200000+01   1.1600000+01
   2.6825000+01 $YBAR  1.8929533-01 $SY  2.6635705+01 $LTLY
   4.5820000+01 $UBAR  2.7750875-01 $SU  4.4224325+01 $LTLU
   1.0680000+01 $EBAR  6.3007999-01 $SE

 LABEL CT3-2 TIG-7106,5180,0.5,5 DAYS
               2              0   5.1200000+01   1.2200000+01
              29   2.9100000+01   4.9000000+01   1.1600000+01
               8   2.9800000+01   5.0000000+01   1.4400000+01
              14   3.0100000+01   4.8900000+01   1.0500000+01
              20   3.0700000+01   5.0300000+01   1.2300000+01
   2.9925000+01 $YBAR  6.6520467-01 $SY  2.9259795+01 $LTLY
   4.9880000+01 $UBAR  9.5760904-01 $SU  4.4373748+01 $LTLU
   1.2200000+01 $EBAR  1.4230253+00 $SE

 LABEL CT3-2,TIG-7106,5180,0.5,9 DAYS
               3   3.2100000+01   5.1100000+01   1.1500000+01
               9   3.1300000+01   5.0600000+01   1.1600000+01
              15   3.1300000+01   4.9600000+01   1.0000000+01
              21   3.1900000+01   5.0600000+01   1.5000000+01
              27   3.1900000+01   4.7200000+01   1.1700000+01
   3.1700000+01 $YBAR  3.7416492-01 $SY  2.9548552+01 $LTLY
   4.9820000+01 $UBAR  1.5626929+00 $SU  4.0834516+01 $LTLU
   1.1960000+01 $EBAR  1.8365733+00 $SE

 LABEL CT3-2,TIG-7106,5180,0.5,2 WEEKS
               4   3.2500000+01   5.1500000+01   1.3100000+01
              10   3.1700000+01   5.1300000+01   1.3400000+01
              16   3.2100000+01   5.1500000+01   1.2350000+01
              22   3.2600000+01   5.1200000+01   1.1300000+01
   3.2075000+01 $YBAR  3.3041118-01 $SY  3.1744589+01 $LTLY
   5.1375000+01 $UBAR  1.5003933-01 $SU  5.1224961+01 $LTLU
   1.2537500+01 $EBAR  9.3574801-01 $SE

 LABEL CT3-2,TIG-7106,5180,0.5,5 WEEKS
               5   3.5000000+01   5.3200000+01   1.3200000+01
              11   3.4500000+01   5.3500000+01   1.1700000+01
              17   3.4400000+01   5.3000000+01   1.2700000+01
              23   3.4700000+01   5.4000000+01   1.3000000+01
              28   3.4300000+01   5.2900000+01   7.5000000+00
   3.4580000+01 $YBAR  2.7748813-01 $SY  3.2984443+01 $LTLY
   5.3320000+01 $UBAR  4.4386821-01 $SU  5.0767643+01 $LTLU
   1.1620000+01 $EBAR  2.3742367+00 $SE

 LABEL CT3-2, TIG-7106, 5180, 0.5, 12 WEEKS
               6   3.6400000+01   5.4200000+01   1.3000000+01
              12   3.5900000+01   5.4700000+01   1.3800000+01
              18   3.5200000+01   5.2600000+01   1.2200000+01
              24   3.5400000+01   5.2700000+01   1.3200000+01
              25   3.6000000+01   5.3100000+01   1.3200000+01
   3.5780000+01 $YBAR  4.5167405-01 $SY  3.3010374+01 $LTLY
   5.3460000+01 $UBAR  9.3968658-01 $SU  4.3056802+01 $LTLU
   1.3080000+01 $EBAR  5.7619588-01 $SE
```

TABLE J-8.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT4-2, 0.50-inch TIG/5356, Sq Butt.

```
          NUMBER         Y               U                E
 LABEL CT4-2,TIG-7106,5356,0.50,1 DAY
               1   2.6900000+01   4.4500000+01   6.7000000+00
               7   2.5900000+01   4.5000000+01   8.7000000+00
              13   2.6300000+01   4.6100000+01   1.0300000+01
              19   2.6800000+01   4.5100000+01   9.0000000+00
              25   2.5800000+01   4.5300000+01   1.0400000+01
              31   2.6300000+01   4.4600000+01   9.5000000+00
   2.6333333+01 $YBAR  4.5018917-01 $SY  2.4055376+01 $LTLY
   4.5100000+01 $UBAR  5.7620034-01 $SU  4.2184426+01 $LTLU
   9.1000000+00 $EBAR  1.3579398+00 $SE

 LABEL CT4-2,TIG-7106,5356,0.50,5 DAYS
               2   3.0100000+01   4.8100000+01   8.4000000+00
               8   3.0600000+01   4.8800000+01   1.0000000+01
              14   2.9900000+01   4.9200000+01   1.0300000+01
              20   3.0900000+01   4.8600000+01   1.0300000+01
              26   2.9700000+01   4.8800000+01   1.0000000+01
              32   2.9100000+01   4.8500000+01   1.0000000+01
   3.0050000+01 $YBAR  6.4420446-01 $SY  2.6790325+01 $LTLY
   4.8666667+01 $UBAR  3.6698798-01 $SU  4.6809707+01 $LTLU
   9.8333333+00 $EBAR  7.1740278-01 $SE

 LABEL CT4-2,TIG-7106,5356,0.50,9 DAYS
               3   3.1000000+01   4.9800000+01   9.0000000+00
               9   3.0800000+01   4.9100000+01   9.2000000+00
              15   3.0800000+01   5.0600000+01   1.3700000+01
              21   3.0700000+01   4.9800000+01   1.3400000+01
              27   3.0400000+01   5.0200000+01   1.1100000+01
              33   3.0200000+01   4.8800000+01   9.2000000+00
   3.0650000+01 $YBAR  2.9496197-01 $SY  2.9157492+01 $LTLY
   4.9716666+01 $UBAR  6.7058834-01 $SU  4.6323489+01 $LTLU
   1.0933333+01 $EBAR  2.1685633+00 $SE
 LABEL CT4-2,TIG-7106,5356,0.50,2 WEEKS
               4   3.2300000+01   5.1100000+01   9.3500000+00
              10   3.2000000+01   5.1200000+01   1.0800000+01
              16   3.1900000+01   5.0600000+01   9.3500000+00
              22   3.1500000+01   5.1300000+01   1.3250000+01
              28   3.1400000+01   5.0500000+01   1.0100000+01
              34   3.1600000+01   5.1200000+01   1.2800000+01
   3.1783333+01 $YBAR  3.4302569-01 $SY  3.0047623+01 $LTLY
   5.0983333+01 $UBAR  3.4303014-01 $SU  4.9247601+01 $LTLU
   1.0941667+01 $EBAR  1.7074593+00 $SE

 LABEL CT4-2,TIG-7106,5356,0.50,5 WEEKS
               5   3.3700000+01   5.3000000+01   1.1300000+01
              11   3.2900000+01   5.2900000+01   1.3200000+01
              17   3.2000000+01   5.2500000+01   1.3200000+01
              23   3.3400000+01   5.2400000+01   1.2400000+01
              29   3.3700000+01   5.2600000+01   1.3000000+01
              35   3.3500000+01   5.2500000+01   1.3000000+01
   3.3200000+01 $YBAR  6.5726995-01 $SY  2.9874214+01 $LTLY
   5.2650000+01 $UBAR  2.4291725-01 $SU  5.1420839+01 $LTLU
   1.2683333+01 $EBAR  7.3669294-01 $SE

 LABEL CT4-2, TIG-7106, 5356, 0.50, 12 WEEKS
               6   3.5400000+01   5.3900000+01   1.1700000+01
              12   3.4900000+01   5.3100000+01   1.3500000+01
              18   3.5100000+01   5.2300000+01   1.3000000+01
              24   3.4900000+01   5.2300000+01   1.1700000+01
              30   3.4900000+01   5.2700000+01   1.2800000+01
              36   3.5500000+01   5.3500000+01   1.3300000+01
   3.5116667+01 $YBAR  2.7142676-01 $SY  3.3743247+01 $LTLY
   5.2966666+01 $UBAR  6.5321097-01 $SU  4.9661419+01 $LTLU
```

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT5-6, 0.50-inch TIG/5556, Sq Butt.

```
         NUMBER            Y               U                E
LABEL CT5-6,TIG-7106,5556,0.50,1 DAY
                 1   2.6000000+01    4.4900000+01    7.7000000+00
                 7   2.7000000+01    4.6100000+01    9.2000000+00
                13   2.6600000+01    4.6100000+01    9.9000000+00
                19   2.7800000+01    4.6100000+01    9.1000000+00
                25   2.6500000+01    4.4800000+01    9.0000000+00
                31   2.7000000+01    4.4400000+01    8.7000000+00
  2.6816667+01 $YBAR  6.0800627-01 $SY  2.3740155+01 $LTLY
  4.5400000+01 $UBAR  7.8486274-01 $SU  4.1428594+01 $LTLU
  8.9333333+00 $EBAR  7.2295721-01 $SE
LABEL CT5-6,TIG-7106,5556,0.5,5 DAYS
                 2   3.0000000+01    4.9100000+01    8.5000000+00
                 8   3.0200000+01    4.9800000+01    9.9000000+00
                14   3.0500000+01    4.9300000+01    9.7000000+00
                20   3.0600000+01    4.8500000+01    9.8000000+00
                26   3.0500000+01    4.8500000+01    9.6000000+00
                32   3.0100000+01    4.7700000+01    9.0000000+00
  3.0316667+01 $YBAR  2.4832815-01 $SY  2.9060126+01 $LTLY
  4.8816667+01 $UBAR  7.3869243-01 $SU  4.5078883+01 $LTLU
  9.4166667+00 $EBAR  5.4924188-01 $SE

LABEL CT5-6,TIG-7106,5556,0.5,9 DAYS
                 3   2.9800000+01    4.8800000+01    9.2000000+00
                 9   3.0100000+01    4.9200000+01    9.4000000+00
                15   3.0800000+01    4.9600000+01    1.0000000+01
                21   3.0700000+01    4.9500000+01    1.0800000+01
                27   3.0000000+01    4.9000000+01    1.0000000+01
                33   3.0400000+01    4.8600000+01    9.2000000+00
  3.0300000+01 $YBAR  3.9999313-01 $SY  2.8276035+01 $LTLY
  4.9116667+01 $UBAR  3.9202094-01 $SU  4.7133041+01 $LTLU
  9.7666667+00 $EBAR  6.2503326-01 $SE

LABEL CT5-6,TIG-7106,5556,0.5,2 WEEKS
                 4   3.0500000+01    5.0100000+01    9.3000000+00
                10   3.1100000+01    5.1000000+01    1.3050000+01
                16   3.1100000+01    5.0400000+01    1.3200000+01
                22   3.0900000+01    4.9200000+01    1.0550000+01
                28   3.0800000+01    4.8500000+01    1.0000000+01
                34   3.0100000+01    4.7900000+01    8.5500000+00
  3.0750000+01 $YBAR  3.8859629-01 $SY  2.8763703+01 $LTLY
  4.9516667+01 $UBAR  1.1889819+00 $SU  4.3500418+01 $LTLU
  1.0775000+01 $EBAR  1.9408117+00 $SE

LABEL CT5-6,TIG-7106,5556,0.0,5WEEKS
                 5   3.5300000+01    5.4000000+01    9.2000000+00
                11   3.4600000+01    5.4000000+01    1.1700000+01
                17   3.4800000+01    5.3300000+01    1.1600000+01
                23   3.2300000+01               0               0
                29   3.4400000+01    5.2300000+01    1.4700000+01
                35   3.3500000+01    5.2300000+01    1.0200000+01
  3.4150000+01 $YBAR  1.0821328+00 $SY  2.8674408+01 $LTLY
  5.3160000+01 $UBAR  6.5264141-01 $SU  4.8277312+01 $LTLU
  1.1480000+01 $EBAR  2.0777394+00 $SE

LABEL CT5-6, TIG-7106, 5556, 0.5, 12 WEEKS
                 6   3.5100000+01    5.4500000+01    1.1200000+01
                12   3.5100000+01    5.3900000+01    1.3200000+01
                18   3.5600000+01    5.3300000+01    1.0900000+01
                24   3.5100000+01    5.2900000+01    1.1200000+01
                30   3.5200000+01    5.2500000+01    1.0000000+01
                36   3.4200000+01    5.2100000+01    1.0200000+01
  3.5050000+01 $YBAR  4.5935241-01 $SY  3.2725677+01 $LTLY
  5.3200000+01 $UBAR  8.9219981-01 $SU  4.8665469+01 $LTLU
  1.1116667+01 $EBAR  1.1391523+00 $SE
```

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT3-4, 0.50-inch TIG/X5180, Double V

```
         NUMBER            Y               U                E
LABEL CT3-4,TIG-7106,5180,0.5,3 DAY
                 1   3.0200000+01    4.8600000+01    8.0000000+00
                 7   2.7500000+01    4.7500000+01    8.2000000+00
                13   2.8200000+01    4.7400000+01    8.7000000+00
                19   2.8500000+01    4.8100000+01    9.7000000+00
                25   2.7900000+01    4.7800000+01    9.7000000+00
                31   2.6500000+01    4.7100000+01    9.0000000+00
  2.8683333+01 $YBAR  3.4715207-01 $SY  2.4596744+01 $LTLY
  4.7750000+01 $UBAR  2.3946995-01 $SU  4.5020282+01 $LTLU
  8.8833333+00 $EBAR  7.2502910-01 $SE

LABEL CT3-4,TIG-7106,5180,0.5,5 DAY
                 2   3.1000000+01    5.0200000+01    8.1000000+00
                 8   3.0500000+01    4.9400000+01    9.0000000+00
                14   3.0100000+01    4.9200000+01    8.9000000+00
                20   3.0200000+01    4.9400000+01    9.0000000+00
                26   3.0700000+01    5.0000000+01    8.7000000+00
                32   3.0500000+01    4.9200000+01    8.7000000+00
  3.0500000+01 $YBAR  3.2863149-01 $SY  2.8837125+01 $LTLY
  4.9566667+01 $UBAR  4.2739445-01 $SU  4.7404051+01 $LTLU
  8.7333333+00 $EBAR  3.3862563-01 $SE

LABEL CT3-4,TIG-7106,5180,0.5,10 DAY
                 3   3.4100000+01    5.2000000+01    8.5000000+00
                 9   3.4300000+01    5.2000000+01    8.2000000+00
                15   3.4800000+01    5.2600000+01    8.5000000+00
                21   3.4500000+01    5.1600000+01    8.8000000+00
                27   3.3600000+01    5.2000000+01    9.0000000+00
                33   3.3500000+01    5.1600000+01    9.1000000+00
  3.4133333+01 $YBAR  5.0859915-01 $SY  3.1559821+01 $LTLY
  5.1966667+01 $UBAR  3.6700461-01 $SU  5.0109623+01 $LTLU
  8.6833333+00 $EBAR  3.4302541-01 $SE

LABEL CT3-4,TIG-7106,5180,0.5,17 DAYS
                 4   3.4800000+01    5.2500000+01    9.3000000+00
                10   3.4800000+01    5.2500000+01    8.7000000+00
                16   3.5100000+01    5.2500000+01    8.8000000+00
                22   3.5200000+01    5.2700000+01    9.6000000+00
                28   3.5400000+01    5.2600000+01    9.5000000+00
                34   3.2500000+01    5.2000000+01    9.3000000+00
  3.4633333+01 $YBAR  1.0708285+00 $SY  2.9214941+01 $LTLY
  5.2466667+01 $UBAR  2.4228829-01 $SU  5.1240688+01 $LTLU
  9.2166667+00 $EBAR  3.6686816-01 $SE

LABEL CT3-4, TIG-7106, 5180, 0.5, 5 WEEKS
                 5   3.4500000+01    5.2400000+01    8.3000000+00
                11   3.4300000+01    5.2900000+01    8.7000000+00
                17   3.4600000+01    5.2900000+01    9.8000000+00
                23   3.3900000+01    5.2800000+01    9.0000000+00
                29   3.3900000+01    5.2300000+01    1.0400000+01
                35   3.5100000+01    5.2400000+01    9.6000000+00
  3.4383333+01 $YBAR  4.5789849-01 $SY  3.2066367+01 $LTLY
  5.2616666+01 $UBAR  2.7872127-01 $SU  5.1206337+01 $LTLU
  9.3000000+00 $EBAR  7.7459716-01 $SE

LABEL CT3-4, TIG-7106, 5180, 0.5, 12 WEEKS
                 6   3.5400000+01    5.3100000+01    9.2000000+00
                12   3.3900000+01    5.1800000+01    7.5000000+00
                18   3.6800000+01    5.2800000+01    9.5000000+00
                24   3.4900000+01    5.3200000+01    1.1100000+01
                30   3.5000000+01    5.3500000+01    1.0000000+01
                36   3.5100000+01    5.2500000+01    9.1000000+00
  3.5183333+01 $YBAR  9.4109986-01 $SY  3.0421368+01 $LTLY
  5.2816667+01 $UBAR  6.0469961-01 $SU  4.9756887+01 $LTLU
  9.4000000+00 $EBAR  1.1832163+00 $SE
```

TABLE J-11.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT4-4, 0.50-inch TIG/5356, Double V

```
       NUMBER             Y                U                 E
LABEL CT4-4,TIG-7106,5356,0.50,3 DAY
             1    2.9000000+01    4.8000000+01    7.5000000+00
             7    2.8500000+01    4.7700000+01    9.2000000+00
            13    2.8900000+01    4.8100000+01    9.0000000+00
            19    2.8600000+01    4.7900000+01    9.2000000+00
            25    2.8000000+01    4.6900000+01    9.0000000+00
            31    2.8600000+01    4.7700000+01    9.6000000+00
  2.8600000+01 $YBAR  3.5214362-01 $SY  2.6818153+01 $LTLY
  4.7716666+01 $UBAR  4.3091444-01 $SU  4.5536239+01 $LTLU
  8.9166667+00 $EBAR  7.2778205-01 $SE

LABEL CT4-4,TIG-7106,5356,0.50,5 DAY
             2    3.0800000+01    4.9500000+01    8.2000000+00
             8    3.0100000+01    4.8900000+01    8.2000000+00
            14    2.9900000+01    4.8800000+01    8.3000000+00
            20    2.9400000+01    4.8600000+01    9.0000000+00
            26    3.2000000+01    4.9000000+01    9.6000000+00
            32    2.9300000+01    4.8100000+01    8.7000000+00
  3.0250000+01 $YBAR  1.0134141+00 $SY  2.5122125+01 $LTLY
  4.8816667+01 $UBAR  4.6224655-01 $SU  4.6477699+01 $LTLU
  8.6666666+00 $EBAR  5.5737530-01 $SE

LABEL CT4-4,TIG-7106,5356,0.50,10 DAY
             3    3.6600000+01    5.1400000+01    9.1000000+00
             9    3.3100000+01    5.1000000+01    9.0000000+00
            15    3.3500000+01    5.1300000+01    9.4000000+00
            21    3.3300000+01    5.0500000+01    9.5000000+00
            27    3.2700000+01    5.1000000+01    9.6000000+00
            33    3.3300000+01    5.1000000+01    1.0200000+01
  3.3750000+01 $YBAR  1.4223256+00 $SY  2.6553032+01 $LTLY
  5.1033333+01 $UBAR  3.1410719-01 $SU  4.9443951+01 $LTLU
  9.4666666+00 $EBAR  4.2739579-01 $SE

LABEL CT4-4,TIG-7106,5356,0.50,17 DAY
             4    3.5000000+01    5.2100000+01    9.3000000+00
            10    3.4100000+01    5.1400000+01    9.3000000+00
            16    3.4100000+01    5.1800000+01    1.0000000+01
            22    3.3900000+01    5.1600000+01    9.8000000+00
            28    3.3600000+01    5.1600000+01    1.0400000+01
            34    3.3900000+01    5.0300000+01    9.5000000+00
  3.4100000+01 $YBAR  4.7749652-01 $SY  3.1683868+01 $LTLY
  5.1466666+01 $UBAR  6.1862471-01 $SU  4.8336425+01 $LTLU
  9.7166666+00 $EBAR  4.3550746-01 $SE

LABEL CT4-4, TIG-7106, 5356, 0.5, 5 WEEKS
             5    3.2100000+01    5.1300000+01    8.3000000+00
            11    3.3000000+01    5.2000000+01    9.1000000+00
            17    3.2800000+01    5.2100000+01    9.3000000+00
            23    3.2500000+01    5.2200000+01    1.0000000+01
            29    3.3100000+01    5.2200000+01    1.0600000+01
            35    3.3600000+01    5.1900000+01    9.2000000+00
  3.2850000+01 $YBAR  5.1672468-01 $SY  3.0235373+01 $LTLY
  5.1950000+01 $UBAR  3.3913810-01 $SU  5.0233961+01 $LTLU
  9.4166666+00 $EBAR  7.9351553-01 $SE

LAREL CT4-4, TIG-7106, 5356, 0.5, 12 WEEKS
             6    3.4500000+01    5.2600000+01    9.7000000+00
            12    3.3500000+01    5.2300000+01    9.2000000+00
            18    3.4100000+01    5.3100000+01    1.0000000+01
            24    3.4100000+01    5.1800000+01    9.7000000+00
            30    3.5000000+01    5.2700000+01    1.0400000+01
            36    3.4300000+01    5.2200000+01    9.4000000+00
  3.4250000+01 $YBAR  4.9700028-01 $SY  3.1735178+01 $LTLY
  5.2450000+01 $UBAR  4.5055846-01 $SU  5.0170174+01 $LTLU
  9.7333333+00 $EBAR  4.2739623-01 $SE
```

TABLE J-12.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT5-8, 0.50-inch TIG/5556, Double V

```
       NUMBER             Y                U                 E
LABEL CT5-8,TIG-7106,5556,0.5,3 DAY
             1    2.9400000+01    4.8200000+01    7.9000000+00
             7    2.7900000+01    4.8300000+01    9.0000000+00
            13    2.8500000+01    4.8500000+01    8.7000000+00
            19    2.8600000+01    4.7500000+01    8.4000000+00
            25    2.8500000+01    4.8800000+01    1.0000000+01
            31    2.8200000+01    4.7300000+01    8.0000000+00
  2.8516667+01 $YBAR  5.0366091-01 $SY  2.5968142+01 $LTLY
  4.8100000+01 $UBAR  5.8309728-01 $SU  4.5149528+01 $LTLU
  8.6666667+00 $EBAR  7.7373559-01 $SE

LABEL CT5-8,TIG-7106,5556,0.5,5 DAY
             2    3.0500000+01    4.9300000+01    8.4000000+00
             8    2.9500000+01    4.9600000+01    9.0000000+00
            14    2.9500000+01    4.9500000+01    8.3000000+00
            20    2.9900000+01    4.9400000+01    9.1000000+00
            26    2.9400000+01    4.9900000+01    8.7000000+00
            32    3.0000000+01    4.9300000+01    8.7000000+00
  2.9800000+01 $YBAR  4.1952834-01 $SY  2.7677187+01 $LTLY
  4.9500000+01 $UBAR  2.2801260-01 $SU  4.8346256+01 $LTLU
  8.7000000+00 $EBAR  3.1622897-01 $SE

LABEL CT5-8,TIG-7106,5556,0.5,10 DAY
             3    3.3800000+01    5.1900000+01    9.2000000+00
             9    3.3500000+01    5.1200000+01    1.0000000+01
            15    3.4200000+01    5.1600000+01    9.2000000+00
            21    3.3300000+01    5.1400000+01    1.1700000+01
            27    3.3100000+01    5.0800000+01    9.2000000+00
            33    3.3800000+01    5.1100000+01    9.4000000+00
  3.3616667+01 $YBAR  3.9707949-01 $SY  3.1607444+01 $LTLY
  5.1333333+01 $UBAR  3.8817985-01 $SU  4.9369143+01 $LTLU
  9.7833333+00 $EBAR  9.8877057-01 $SE

LABEL CT5-8,TIG-7106,5556,0.5,17 DAY
             1    3.4600000+01    5.2000000+01    9.5000000+00
            10    3.4500000+01    5.1500000+01    9.7000000+00
            16    3.4700000+01    5.1600000+01    9.5000000+00
            22    3.4100000+01    5.1800000+01    1.0000000+01
            28    3.4200000+01    5.0600000+01    9.5000000+00
            34    3.4100000+01    5.1500000+01    9.6000000+00
  3.4366667+01 $YBAR  2.6584320-01 $SY  3.3021500+01 $LTLY
  5.1500000+01 $UBAR  4.8169622-01 $SU  4.9062617+01 $LTLU
  9.6333333+00 $EBAR  1.9663808-01 $SE

LABEL CT5-8, TIG-7106, 5556, 0.5, 5 WEEKS
             5    3.3100000+01    5.2800000+01    9.0000000+00
            11    3.1900000+01    5.2100000+01    9.6000000+00
            17    3.2000000+01    5.1600000+01    8.4000000+00
            23    3.2700000+01    5.1700000+01    9.8000000+00
            29    3.2800000+01    5.1900000+01    1.0000000+01
            35    3.3000000+01    5.1300000+01    8.0000000+00
  3.2583333+01 $YBAR  5.1153981-01 $SY  2.9994942+01 $LTLY
  5.1900000+01 $UBAR  5.1770414-01 $SU  4.9280417+01 $LTLU
  9.1333333+00 $EBAR  8.0663921-01 $SE

LABEL CT5-8, TIG-7106, 5556, 0.5, 12 WEEKS
             6    3.4200000+01    5.2900000+01    9.5000000+00
            12    3.2700000+01    5.3200000+01    1.0000000+01
            18    3.2700000+01    5.3800000+01    1.0000000+01
            24    3.3900000+01    5.2600000+01    1.0100000+01
            30    3.4100000+01    5.1400000+01    8.5000000+00
            36    3.3600000+01    5.1700000+01    8.1000000+00
  3.3533333+01 $YBAR  6.7725408-01 $SY  3.0106427+01 $LTLY
  5.2600000+01 $UBAR  9.7994666-01 $SU  4.7995670+01 $LTLU
  9.3666667+00 $EBAR  6.6178086-01 $SE
```

TABLE J-13.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM3-2, 0.50-inch MIG/X5180, Double V

```
          NUMBER               Y                U                 E
LABEL CM3-2,MIG-7106,5180,0.50,1 DAY
                   1   2.6000000+01   4.5900000+01   9.4000000+00
                   7   2.5500000+01   4.3700000+01   9.2000000+00
                  13   2.6100000+01   4.5500000+01   1.0000000+01
                  19   2.6700000+01   4.5900000+01   1.1800000+01
                  25   2.7500000+01   4.3900000+01   9.0000000+00
                  31   2.6400000+01   4.3700000+01   7.9000000+00
  2.6366667+01 $YBAR  6.8605139-01 $SY  2.2895247+01 $LTLY
  4.4766667+01 $UBAR  1.1075497+00 $SU  3.9162465+01 $LTLU
  9.5500000+00 $EBAR  1.2988457+00 $SE

LABEL CM3-2,MIG-7106,5180,0.50,4 DAYS
                   2   2.8400000+01   4.6800000+01   8.2000000+00
                   8   2.8100000+01   4.6800000+01   7.2000000+00
                  14   3.5700000+01   4.8200000+01   1.0200000+01
                  20   2.9400000+01   4.7100000+01   9.1000000+00
                  26   3.0600000+01   4.5600000+01   8.7000000+00
                  32   3.0900000+01   4.7100000+01   8.5000000+00
  3.0516667+01 $YBAR  2.7780705+00 $SY  1.6459630+01 $LTLY
  4.6933333+01 $UBAR  8.3347696-01 $SU  4.2715940+01 $LTLU
  8.6500000+00 $EBAR  9.9347887-01 $SE

LABEL CM3-2,MIG-7106,5180,0.50,7 DAYS
                   3   3.0200000+01   4.2000000+01   5.2000000+00
                   9   3.1100000+01   4.7100000+01   7.2000000+00
                  15   3.0700000+01   4.9800000+01   9.5000000+00
                  21   3.0700000+01   4.9200000+01   9.3000000+00
                  27   3.0800000+01   4.7100000+01   8.1000000+00
                  33   3.0600000+01   4.8800000+01   8.6000000+00
  3.0683333+01 $YBAR  2.9269258-01 $SY  2.9202309+01 $LTLY
  4.7333333+01 $UBAR  2.8380781+00 $SU  3.2972658+01 $LTLU
  7.9833333+00 $EBAR  1.5992708+00 $SE

LABEL CM3-2,MIG-7106,5180,0.50,2 WEEKS
                   4   3.1700000+01   4.8300000+01   6.5000000+00
                  10   3.0900000+01   5.0200000+01   8.1000000+00
                  16   3.1800000+01   5.1500000+01   9.2000000+00
                  22   3.1500000+01   5.0500000+01   8.3000000+00
                  28   3.1800000+01   5.0600000+01   8.7000000+00
                  34   3.1800000+01   5.0800000+01   8.8000000+00
  3.1583333+01 $YBAR  3.5450160-01 $SY  2.9789555+01 $LTLY
  5.0316667+01 $UBAR  1.0796581+00 $SU  4.4853597+01 $LTLU
  8.2666666+00 $EBAR  9.4798066-01 $SE

LABEL CM3-2,MIG-7106,5180,0.50,5 WEEKS
                   5   3.2500000+01   5.0000000+01   6.2000000+00
                  11   3.2200000+01   5.0800000+01   8.4000000+00
                  17   3.2900000+01   5.3300000+01   1.1200000+01
                  23   3.3100000+01   5.0800000+01   9.6000000+00
                  29   3.2000000+01   5.2000000+01   9.6000000+00
                  35   3.2500000+01   5.0200000+01   7.2000000+00
  3.2533333+01 $YBAR  4.1311803-01 $SY  3.0442956+01 $LTLY
  5.1183333+01 $UBAR  1.2496728+00 $SU  4.4859989+01 $LTLU
  8.7000000+00 $EBAR  1.8143870+00 $SE

LABEL CM3-2, MIG-7106, 5180, 0.50, 12 WEEKS
                   6   3.3900000+01   4.9400000+01   6.2000000+00
                  12   3.5200000+01   5.2900000+01   8.1000000+00
                  18   3.4900000+01   5.4600000+01   1.0200000+01
                  24   3.5400000+01   5.3200000+01   8.4000000+00
                  30   3.4500000+01   5.1900000+01   8.5000000+00
                  36   3.5100000+01   5.1200000+01   6.8000000+00
  3.4833333+01 $YBAR  5.5015478-01 $SY  3.2049550+01 $LTLY
  5.2200000+01 $UBAR  1.7988881+00 $SU  4.3097626+01 $LTLU
  8.0333333+00 $EBAR  1.4094918+00 $SE
```

TABLE J-14.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM4-2, 0.50-inch MIG/5356, Double V

```
          NUMBER               Y                U                 E
LABEL CM4-2,MIG-7106,5356,0.50,1 DAY
                   1   2.3700000+01   4.4500000+01   9.5000000+00
                   7              0   4.4200000+01   8.3000000+00
                  39   2.4300000+01   4.4700000+01   9.0000000+00
                  13   2.4700000+01   4.3100000+01   8.7000000+00
                  19   2.3400000+01   4.4300000+01   9.5000000+00
                  25   2.4300000+01   4.5200000+01   8.7000000+00
                  31   2.4200000+01   4.4400000+01   9.5000000+00
  2.4100000+01 $YBAR  4.6903962-01 $SY  2.1726659+01 $LTLY
  4.4342857+01 $UBAR  6.3995376-01 $SU  4.1373471+01 $LTLU
  9.0285714+00 $EBAR  4.8550447-01 $SE

LABEL CM4-2,MIG-7106,5356,0.50,4 DAYS
                   2   2.7100000+01   4.7400000+01   1.0400000+01
                   8   2.4700000+01   4.5500000+01   8.3000000+00
                  14   2.5800000+01   4.3600000+01   7.1000000+00
                  20   2.4800000+01   4.5900000+01   9.3000000+00
                  26   2.5300000+01   4.5600000+01   9.3000000+00
                  32   2.5300000+01   4.6100000+01   9.4000000+00
  2.5500000+01 $YBAR  8.7863885-01 $SY  2.1054087+01 $LTLY
  4.5683333+01 $UBAR  1.2286929+00 $SU  3.9466147+01 $LTLU
  8.9666666+00 $EBAR  1.1307815+00 $SE

LABEL CM4-2,MIG-7106,5356,0.50,7 DAYS
                   3   2.6600000+01   4.8400000+01   9.2000000+00
                   9   2.6300000+01   4.7900000+01   7.2000000+00
                  15   2.5200000+01   4.6100000+01   7.2000000+00
                  21   2.5200000+01   4.7900000+01   8.3000000+00
                  27   2.6600000+01   4.7700000+01   9.0000000+00
                  33   2.6500000+01   4.6100000+01   8.1000000+00
  2.6066667+01 $YBAR  6.8019804-01 $SY  2.2624865+01 $LTLY
  4.7350000+01 $UBAR  9.9548848-01 $SU  4.2312828+01 $LTLU
  8.1666666+00 $EBAR  8.5479080-01 $SE

LABEL CM4-2,MIG-7106,5356,0.5,2 WEEKS
                   4   2.6900000+01   4.8400000+01   8.8000000+00
                  10   2.6200000+01   4.8100000+01   8.3000000+00
                  16   2.6400000+01   4.8700000+01   8.7000000+00
                  22   2.6300000+01   4.7900000+01   8.7000000+00
                  28   2.7900000+01   4.9300000+01   8.5000000+00
                  34   2.8000000+01   4.8200000+01   7.3000000+00
  2.6950000+01 $YBAR  8.1178980-01 $SY  2.2842344+01 $LTLY
  4.8433333+01 $UBAR  5.0466573-01 $SU  4.5879725+01 $LTLU
  8.3833333+00 $EBAR  5.6005991-01 $SE

LABEL CM4-2,MIG-7106,5356,0.50,5 WEEKS
                   5   2.7700000+01   4.6500000+01   6.2000000+00
                  11   2.8200000+01   4.8000000+01   6.7000000+00
                  17   2.7400000+01   4.9700000+01   7.2000000+00
                  23   2.7900000+01   4.8200000+01   7.0000000+00
                  29   2.8600000+01   5.0600000+01   8.0000000+00
                  35   2.8600000+01   4.9400000+01   7.5000000+00
  2.8066667+01 $YBAR  4.8853743-01 $SY  2.5594667+01 $LTLY
  4.8733333+01 $UBAR  1.4610482+00 $SU  4.1340429+01 $LTLU
  7.1000000+00 $EBAR  6.2609919-01 $SE

LABEL CM4-2, MIG-7106, 5356, 0.50, 12 WEEKS
                   6   2.9500000+01   5.0000000+01   7.3000000+00
                  12   2.9300000+01   4.9600000+01   7.5000000+00
                  18   2.9300000+01   5.0400000+01   8.0000000+00
                  24   2.9500000+01   5.1200000+01   8.6000000+00
                  30   3.0200000+01   4.9200000+01   6.2000000+00
                  36   3.0300000+01   5.0800000+01   7.8000000+00
  2.9683333+01 $YBAR  4.4907946-01 $SY  2.7410991+01 $LTLY
  5.0200000+01 $UBAR  7.4832985-01 $SU  4.6413451+01 $LTLU
  7.5666666+00 $EBAR  6.0663956-01 $SE
```

TABLE J-15.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM5-1, 0.50-inch MIG/5556, Double V

```
        NUMBER             Y              U               E
 LABEL CM5-1,MIG-7106,5556,0.5,1 DAY
            1   2.8000000+01   4.6600000+01    9.9000000+00
            7   2.8200000+01   4.2400000+01    7.6000000+00
           13   2.8900000+01   4.4600000+01    8.3000000+00
           19   2.8900000+01   4.2200000+01    7.8000000+00
           25   2.9800000+01   4.3700000+01    8.7000000+00
           31   2.8700000+01   4.3400000+01    8.9000000+00
   2.8750000+01 $YBAR  6.3482992-01 $SY  2.5537760+01 $LTLY
   4.3816667+01 $UBAR  1.6228595+00 $SU  3.5604997+01 $LTLU
   8.5333333+00 $EBAR  8.3586311-01 $SE

 LABEL CM5-1,MIG-7106,5556,0.5,6 DAYS
            2   3.0700000+01   4.7700000+01    8.3000000+00
            8   3.1400000+01   4.5000000+01    5.2000000+00
           14   3.1500000+01   4.6900000+01    8.4000000+00
           20              0   4.4900000+01    7.2000000+00
           26   3.2000000+01   4.6600000+01    6.9000000+00
           32   3.2000000+01   4.8000000+01    7.9000000+00
           39   3.2100000+01   4.8900000+01    1.1000000+01
   3.1616667+01 $YBAR  5.3448007-01 $SY  2.8912197+01 $LTLY
   4.6857143+01 $UBAR  1.5020653+00 $SU  3.9887560+01 $LTLU
   7.8428571+00 $EBAR  1.7690461+00 $SE

 LABEL CM5-1,MIG-7106,5556,0.5,9 DAYS
            3   3.2100000+01   4.9400000+01    8.4000000+00
            9   3.2200000+01   4.8000000+01    7.8000000+00
           15   3.2400000+01   4.6900000+01    7.8000000+00
           21   3.2000000+01   4.7800000+01    7.6000000+00
           27   3.2400000+01   4.8000000+01    7.7000000+00
           33   3.2800000+01   4.7800000+01    8.1000000+00
   3.2316667+01 $YBAR  2.8577096-01 $SY  3.0870666+01 $LTLY
   4.7983333+01 $UBAR  8.0602134-01 $SU  4.3904865+01 $LTLU
   7.9000000+00 $EBAR  2.9664780-01 $SE

 LABEL CM5-1,MIG-7106,5556,0.5,2 WEEKS
            4   3.2000000+01   4.7000000+01    7.2000000+00
           10   3.1800000+01   4.8000000+01    7.1000000+00
           16   3.2700000+01   4.7800000+01    8.4000000+00
           22   3.2900000+01   4.8600000+01    7.8000000+00
           28   3.3400000+01   4.9200000+01    9.8000000+00
           34   3.3500000+01   4.9300000+01    8.4000000+00
   3.2716667+01 $YBAR  7.0261917-01 $SY  2.9161414+01 $LTLY
   4.8316667+01 $UBAR  8.8637968-01 $SU  4.3831585+01 $LTLU
   8.1166666+00 $EBAR  9.9682839-01 $SE

 LABEL CM5-1,MIG-7106,5556,0.5,5 WEEKS
            5   3.1200000+01   4.8400000+01    6.4000000+00
           11   3.1400000+01   4.9500000+01    6.8000000+00
           17   3.1500000+01   4.9200000+01    6.0000000+00
           23   3.1400000+01   4.9800000+01    6.6000000+00
           29   3.0500000+01   4.9400000+01    6.6000000+00
           35   3.0000000+01   5.1800000+01    8.7500000+00
   3.1000000+01 $YBAR  6.0992563-01 $SY  2.7913776+01 $LTLY
   4.9683333+01 $UBAR  1.1391579+00 $SU  4.3919194+01 $LTLU
   6.8583333+00 $EBAR  9.6561727-01 $SE

 LABEL CM5-1, MIG-7106, 5556, 0.5, 12 WEEKS
            6   3.6800000+01   5.2200000+01    8.8000000+00
           12   3.6500000+01   5.2200000+01    8.2000000+00
           18   3.6800000+01   5.2700000+01    8.4000000+00
           24   3.5900000+01   4.9800000+01    6.5000000+00
           30   3.6800000+01   5.1200000+01    7.1000000+00
           36   3.7200000+01   5.3500000+01    9.5000000+00
   3.6666667+01 $YBAR  4.3666214-01 $SY  3.4457166+01 $LTLY
```

TABLE J-16.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT3-3, 1.00-inch TIG/X5180, Double V

```
        NUMBER             Y              U               E
 LABEL CT3-3,TIG-7106,5180,1.00 INCH,1 DAY
            1   3.1390000+01              0               0
            7   3.0800000+01   4.5500000+01    1.6500000+01
           13   3.0200000+01   4.5600000+01    1.7200000+01
           19   3.0400000+01   4.1800000+01    1.6000000+01
           25   2.9000000+01              0               0
           31   2.9600000+01              0               0
   3.0[illegible]16667+01 $YBAR  5.2563193-01 $SY  2.6038969+01 $LTLY
   4.4[illegible]00000+01 $UBAR  2.1656449+00 $SU  4.2134355+01 $LTLU
   1.6566667+01 $EBAR  5.0277326-01 $SE

 LABEL CT3-3,TIG-7106,5180,1.00INCH,4 DAY
            2   3.3400000+01   4.7200000+01    1.3300000+01
            8   3.2200000+01   4.6400000+01               0
           14   3.2100000+01   4.5900000+01    1.3700000+01
           20   3.2200000+01              0               0
           26   3.0800000+01              0               0
           32   3.1000000+01              0               0
   3.1950000+01 $YBAR  9.4604665-01 $SY  2.7163004+01 $LTLY
   4.6500000+01 $UBAR  6.5573827-01 $SU  4.5844262+01 $LTLU
   1.3500000+01 $EBAR  2.8284426-01 $SE

 LABEL CT3-3,TIG-7106,5180,1.00INCH,8 DAY
            3   3.5100000+01   4.8300000+01    1.5300000+01
            9   3.3800000+01   4.6200000+01               0
           15   3.3800000+01   4.6300000+01               0
           21   3.1800000+01              0               0
           27   3.2500000+01              0               0
           33   3.2400000+01              0               0
   3.3233333+01 $YBAR  1.2176515+00 $SY  2.7072017+01 $LTLY
   4.6933333+01 $UBAR  1.1846311+00 $SU  4.5748702+01 $LTLU
   1.5300000+01 $EBAR  2.4061597+38 $SE

 LABEL CT3-3,TIG-7106,5180,1.00INCH, 2 WEEKS
            4   3.4700000+01   4.9000000+01    1.6700000+01
           10   3.4500000+01   4.6900000+01               0
           16   3.4800000+01   4.6700000+01               0
           22   3.2700000+01              0               0
           28   3.4900000+01              0               0
           34   3.4600000+01              0               0
   3.4366667+01 $YBAR  5.2865549-01 $SY  3.0173670+01 $LTLY
   4.7533333+01 $UBAR  1.2740964+00 $SU  4.6259237+01 $LTLU
   1.6700000+01 $EBAR  2.4061597+38 $SE

 LABEL CT3-3, TIG-7106, 5180, 1.00 INCH 5 WEEKS
            5   3.5200000+01   4.8800000+01               0
           11   3.4500000+01   4.7500000+01               0
           17   3.4600000+01   4.7000000+01               0
           23   3.3700000+01              0               0
           29   3.4700000+01              0               0
           35   3.3700000+01              0               0
   3.4400000+01 $YBAR  5.9330010-01 $SY  3.1397901+01 $LTLY
   4.7766667+01 $UBAR  9.2916214-01 $SU  4.6837504+01 $LTLU
   5.7896044+76 $EBAR              0 $SE

 LABEL CT3-3, TIG-7106, 5180, 1.00 INCH 12 WEEKS
            6   3.3400000+01   4.9400000+01               0
           12   3.6300000+01   4.7600000+01               0
           18   3.6400000+01   4.7500000+01               0
           24   3.5800000+01              0               0
           30   3.5100000+01              0               0
           36   3.6600000+01              0               0
   3.5600000+01 $YBAR  1.2049917+00 $SY  2.9502742+01 $LTLY
   4.8166667+01 $UBAR  1.0692677+00 $SU  4.7097399+01 $LTLU
```

TABLE J-17.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT4-3, 1.00-inch TIG/5356, Double V

```
      NUMBER            Y                 U                E
 LABEL CT4-3,TIG-7106,5356,1.00INCH,36 HOURS
                1    3.0600000+01                0                 0
                7    3.0400000+01     4.5200000+01     1.4200000+01
               13    3.2100000+01     4.6000000+01     1.5000000+01
               19    3.2200000+01     4.6400000+01     1.4600000+01
               25    3.1800000+01     4.6400000+01     1.5000000+01
               31    3.1500000+01     4.6400000+01     1.5500000+01
   3.1433333+01 $YBAR  7.6594381-01 $SY  2.7557558+01 $LTLY
   4.6080000+01 $UBAR  5.2153192-01 $SU  4.3081191+01 $LTLU
   1.4860000+01 $EBAR  4.8785333-01 $SE

 LABEL CT4-3,TIG-7106,5356,1.00,5 DAY
                2    3.2900000+01                0                 0
                8    3.1800000+01     4.5800000+01     1.1700000+01
               14    3.3100000+01     4.6700000+01     1.4500000+01
               20    3.2700000+01     4.6800000+01     1.4500000+01
               26    3.2900000+01     4.7000000+01     1.4500000+01
               32    3.2800000+01     4.7600000+01     1.6500000+01
   3.2700000+01 $YBAR  4.6043736-01 $SY  3.0370187+01 $LTLY
   4.6780000+01 $UBAR  6.4962476-01 $SU  4.3044657+01 $LTLU
   1.4340000+01 $EBAR  1.7111407+00 $SE

 LABEL CT4-3,TIG-7106,5356,1.00INCH,9 DAY
                3    3.3700000+01     4.5900000+01     1.2100000+01
                9    3.3900000+01     4.7200000+01     1.3300000+01
               15    3.4100000+01     4.7800000+01     1.4700000+01
               21    3.4300000+01     4.8300000+01     1.5300000+01
               27    3.4000000+01     4.8300000+01     1.4500000+01
               33    3.3900000+01     4.8100000+01     1.7000000+01
   3.3983333+01 $YBAR  2.0413660-01 $SY  3.2950402+01 $LTLY
   4.7600000+01 $UBAR  9.2953321-01 $SU  4.2896562+01 $LTLU
   1.4483333+01 $EBAR  1.0609722+00 $SE

 LABEL CT4-3,TIG-7106,5356,1.00INCH,2WEEKS + 1 DAY
                4               0     4.6900000+01     1.3500000+01
               10    3.4700000+01     4.8600000+01     1.3500000+01
               16    3.4800000+01     4.9300000+01     1.5200000+01
               22    3.4600000+01     4.9700000+01     1.5000000+01
               28    3.4700000+01     4.9200000+01     1.7000000+01
               34    3.4500000+01     4.9000000+01     1.6500000+01
   3.4660000+01 $YBAR  1.1400295-01 $SY  3.4004483+01 $LTLY
   4.8783333+01 $UBAR  9.9080551-01 $SU  4.3769857+01 $LTLU
   1.5116667+01 $EBAR  1.4634441+00 $SE

 LABEL CT4-3, TIG-7106, 5356, 1.00 INCH 5 WEEKS + 1 DAY
                5    3.5500000+01     4.8700000+01     1.2200000+01
               11    3.6100000+01     4.9900000+01     1.3200000+01
               17    3.6100000+01     5.0600000+01     1.4000000+01
               23    3.6000000+01     5.0600000+01     1.5600000+01
               29    3.5900000+01     4.9800000+01     1.5200000+01
               35    3.6100000+01     4.9000000+01     1.4500000+01
   3.5950000+01 $YBAR  2.3453120-01 $SY  3.4763272+01 $LTLY
   4.9766667+01 $UBAR  7.9162640-01 $SU  4.5761037+01 $LTLU
   1.4116667+01 $EBAR  1.2687260+00 $SE

 LABEL CT4-3, TIG-7106, 5356, 1.00 INCH 12 WEEKS
                6    3.7500000+01     5.2200000+01     1.3900000+01
               12    3.7300000+01     5.2200000+01     1.5100000+01
               18    3.7400000+01     5.1800000+01     1.4300000+01
               24    3.6900000+01     5.0900000+01     1.4000000+01
               30    3.6900000+01     5.0900000+01     1.4300000+01
               36    3.6300000+01     5.0200000+01     1.4100000+01
   3.7050000+01 $YBAR  4.4609991-01 $SY  3.4792734+01 $LTLY
   5.1366667+01 $UBAR  8.2138323-01 $SU  4.7210467+01 $LTLU
   1.4283333+01 $EBAR  4.3089054-01 $SE
```

TABLE J-18.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CT5-7, 1.00-inch TIG/5556, Double V

```
      NUMBER            Y                 U                E
 LABEL CT5-7,TIG-7106,5556,1.00INCH,36 HOURS
                1    3.3500000+01                0                 0
                7    3.3700000+01     4.7500000+01     1.4200000+01
               13    3.3200000+01     4.8200000+01     1.5200000+01
               19    3.3100000+01     4.8400000+01     1.4200000+01
               25    3.3500000+01     4.8500000+01     1.4300000+01
               31    3.3300000+01     4.8700000+01     1.5000000+01
   3.3383333+01 $YBAR  2.2287544-01 $SY  3.2255583+01 $LTLY
   4.8260000+01 $UBAR  4.5153298-01 $SU  4.5606185+01 $LTLU
   1.4580000+01 $EBAR  4.8166613-01 $SE

 LABEL CT5-7,TIG-7106,5556,1.00INCH 5 DAY
                2    3.4700000+01                0                 0
                8    3.4100000+01     4.7800000+01     1.3000000+01
               14    3.3800000+01     4.8400000+01     1.4200000+01
               20    3.3800000+01     4.8500000+01     1.4200000+01
               26    3.5700000+01     4.8700000+01     1.4700000+01
               32    3.4100000+01     4.8700000+01     1.4700000+01
   3.4366667+01 $YBAR  7.3121202-01 $SY  3.0666734+01 $LTLY
   4.8420000+01 $UBAR  3.7016743-01 $SU  4.6291537+01 $LTLU
   1.4160000+01 $EBAR  6.9498221-01 $SE

 LABEL CT5-7,TIG-7106,5556,1.00INCH,9 DAY
                3    3.5200000+01                0                 0
                9    3.4800000+01     4.9400000+01     1.3100000+01
               15    3.5400000+01     4.9800000+01     1.4000000+01
               21    3.5600000+01     4.9200000+01     1.3200000+01
               27    3.5600000+01     4.9900000+01     1.3200000+01
               33    3.5600000+01     4.9900000+01     1.4000000+01
   3.5366667+01 $YBAR  3.2042681-01 $SY  3.3745307+01 $LTLY
   4.9640000+01 $UBAR  3.2091930-01 $SU  4.7794714+01 $LTLU
   1.3500000+01 $EBAR  4.5825917-01 $SE

 LABEL CT5-7,TIG-7106,5556,1.00INCH,2 WEEKS + 2 DAY
                4    3.6100000+01     5.0700000+01     1.3000000+01
               10    3.5500000+01     5.0500000+01     1.4000000+01
               16    3.5700000+01     5.0400000+01     1.2500000+01
               22    3.5400000+01     5.0300000+01     1.3700000+01
               28    3.6300000+01     5.0800000+01     1.4000000+01
               34    3.6200000+01                0                 0
   3.5866667+01 $YBAR  3.6297191-01 $SY  3.3928829+01 $LTLY
   5.0540000+01 $UBAR  2.0738104-01 $SU  4.9347559+01 $LTLU
   1.3440000+01 $EBAR  6.5558305-01 $SE

 LABEL CT5-7, TIG-7106, 5556, 1.00, 5WEEKS + 1 DAY
                5    3.7800000+01                0                 0
               11    3.7300000+01     5.1300000+01     1.3500000+01
               17    3.8000000+01     5.2100000+01     1.4100000+01
               23    3.6700000+01     5.1700000+01     1.1500000+01
               29    3.7100000+01     5.2400000+01     1.3500000+01
               35    3.7100000+01     5.2200000+01     1.3000000+01
   3.7333333+01 $YBAR  4.8443170-01 $SY  3.4882109+01 $LTLY
   5.1940000+01 $UBAR  4.3931856-01 $SU  4.9413918+01 $LTLU
   1.3120000+01 $EBAR  9.8590091-01 $SE

 LABEL CT5-7, TIG-7106, 5556, 1.00 INCH 12 WEEKS
                6    3.9200000+01     5.2200000+01     1.3400000+01
               12    3.8200000+01     5.3000000+01     1.3600000+01
               18    3.7900000+01     5.2800000+01     1.3800000+01
               24    3.8300000+01     5.2200000+01     1.4500000+01
               30    3.9000000+01     5.3600000+01     1.4300000+01
               36    3.8800000+01     5.3000000+01     1.3200000+01
   3.8566666+01 $YBAR  5.0860515-01 $SY  3.5993124+01 $LTLY
   5.2800000+01 $UBAR  5.3665677-01 $SU  5.0084517+01 $LTLU
   1.3800000+01 $EBAR  5.0990255-01 $SE
```

TABLE J-19.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM3-3, 1.00-inch MIG/X5180, Double V

```
           NUMBER            Y              U               E
LABEL CM3-3,MIG-7106,5180,1.00INCH,1DAY
                 1    3.2000000+01    4.1900000+01    1.1700000+01
                 7    3.2200000+01    4.2400000+01    1.1400000+01
                13    3.3800000+01    4.2100000+01    1.2000000+01
                19    3.0900000+01    4.2300000+01    1.0200000+01
                25    3.2300000+01    4.2500000+01    1.0200000+01
                31    3.5200000+01    4.1300000+01    1.0500000+01
   3.2733333+01 $YBAR   1.5227212+00 $SY   2.5026364+01 $LTLY
   4.2083333+01 $UBAR   4.4008028-01 $SU   3.9856527+01 $LTLU
   1.1000000+01 $EBAR   7.9749708-01 $SE

LABEL CM3-3,MIG-7106,5180,1.00INCH,5DAY
                 2    3.2400000+01    4.3900000+01    8.4000000+00
                 8    3.4100000+01    4.3700000+01    8.0000000+00
                14    3.0000000+01    4.4300000+01    8.5000000+00
                20    3.1900000+01    4.2800000+01    1.0100000+01
                26    3.4100000+01    4.3600000+01    8.8000000+00
                32    3.2300000+01    4.3600000+01    7.8000000+00
   3.2466667+01 $YBAR   1.5344941+00 $SY   2.4702126+01 $LTLY
   4.3650000+01 $UBAR   4.9296813-01 $SU   4.1155581+01 $LTLU
   8.6000000+00 $EBAR   8.1731304-01 $SE

LABEL CM3-3,MIG-7106,5180,1.00 INCH,9 DAY
                 3    3.5300000+01    4.5900000+01    9.0000000+00
                 9    3.5500000+01    4.5100000+01    9.0000000+00
                15    3.5700000+01    4.5000000+01    9.2000000+00
                21    3.5200000+01    4.5600000+01    9.7000000+00
                27    3.6000000+01    4.5100000+01    8.5000000+00
                33    3.5400000+01    4.3200000+01    8.0000000+00
   3.5516667+01 $YBAR   2.9268215-01 $SY   3.4035695+01 $LTLY
   4.4983333+01 $UBAR   9.4110310-01 $SU   4.0221352+01 $LTLU
   8.9000000+00 $EBAR   5.8651534-01 $SE

LABEL CM3-3,MIG-7106,5180,1.00INCH,2WKS+1DAY
                 4    3.5200000+01    4.5800000+01    7.0000000+00
                10    3.5200000+01    4.4700000+01    7.0000000+00
                16    3.5000000+01    4.3500000+01    7.5000000+00
                22    3.4800000+01    4.5800000+01    8.2000000+00
                28    3.5300000+01    4.3700000+01    7.8000000+00
                34    3.5800000+01    4.4700000+01    8.4000000+00
   3.5216666+01 $YBAR   3.3716618-01 $SY   3.3510606+01 $LTLY
   4.4700000+01 $UBAR   9.8590531-01 $SU   3.9711319+01 $LTLU
   7.6500000+00 $EBAR   5.9245255-01 $SE

LABEL CM3-3, MIG-7106, 5180, 1.00 INCH 5 WEEK
                 5    3.6600000+01    4.6800000+01    9.1000000+00
                11    3.7500000+01    4.6600000+01    8.1000000+00
                17    3.8100000+01    4.6300000+01    8.7000000+00
                23    3.6700000+01    4.6400000+01    8.7000000+00
                29    3.7300000+01    4.5600000+01    6.9000000+00
                35    3.6500000+01    4.6200000+01    7.5000000+00
   3.7116667+01 $YBAR   6.2743179-01 $SY   3.3941862+01 $LTLY
   4.6316667+01 $UBAR   4.1191216-01 $SU   4.4232391+01 $LTLU
   8.1666666+00 $EBAR   8.3586323-01 $SE

LABEL CM3-3, MIG-7106, 5180, 1.00 INCH 12 WEEKS
                 6    3.9400000+01    4.8700000+01    7.1000000+00
                12    4.0300000+01    4.8500000+01    6.2500000+00
                18    3.9700000+01    4.7900000+01    7.1000000+00
                24    4.0200000+01    4.7700000+01    7.7000000+00
                30    3.9800000+01    4.6500000+01    7.2000000+00
                36    3.9200000+01    4.7100000+01    8.7000000+00
   3.9766666+01 $YBAR   4.3206727-01 $SY   3.7580406+01 $LTLY
```

TABLE J-20.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM4-3, 1.00-inch MIG/5356, Double V

```
           NUMBER            Y              U               E
LABEL CM4-3,MIG-7106,5356,1.00INCH,1DAY
                 1    3.0600000+01    4.0100000+01    9.3000000+00
                 7    3.1100000+01    4.0700000+01    9.5000000+00
                13    3.2000000+01    4.1100000+01    9.5000000+00
                19    3.1400000+01    4.1800000+01    9.7000000+00
                25    3.2000000+01    4.2200000+01    9.7000000+00
                31    3.1000000+01    4.2100000+01    1.0000000+01
   3.1350000+01 $YBAR   5.6480377-01 $SY   2.8492093+01 $LTLY
   4.1333333+01 $UBAR   8.4063734-01 $SU   3.7079708+01 $LTLU
   9.6166666+00 $EBAR   2.4913988-01 $SE

LABEL CM4-3,MIG-7106,5356,1.00INCH,7DAY
                 2    3.1700000+01    4.0600000+01    8.2000000+00
                 8    3.0300000+01    4.1800000+01    8.0000000+00
                14    3.2900000+01    4.1900000+01    9.0000000+00
                20    3.3100000+01    4.1100000+01    8.8000000+00
                26    3.1000000+01    4.1400000+01    9.5000000+00
                32    3.3000000+01    4.1900000+01    8.7000000+00
   3.2000000+01 $YBAR   1.1832147+00 $SY   2.6012934+01 $LTLY
   4.1450000+01 $UBAR   5.2440442-01 $SU   3.8796514+01 $LTLU
   8.7000000+00 $EBAR   5.4405891-01 $SE

LABEL CM4-3,MIG-7106,5356,1.00 INCH,7DAY
                 3    3.3300000+01    4.0300000+01    8.5000000+00
                 9    3.3800000+01    4.2100000+01    8.5000000+00
                15    3.3000000+01    4.2200000+01    9.2000000+00
                21               0    4.1400000+01    9.0000000+00
                27    3.3500000+01    4.1200000+01    8.2000000+00
                33    3.3300000+01    4.2600000+01    8.5000000+00
   3.3380000+01 $YBAR   2.9497361-01 $SY   3.1683902+01 $LTLY
   4.1633333+01 $UBAR   8.3586813-01 $SU   3.7403840+01 $LTLU
   8.6500000+00 $EBAR   3.7282747-01 $SE

LABEL CM4-3,MIG-7106,5356,1.00INCH 2 WEEKS
                 4    3.2200000+01    4.1200000+01    7.2000000+00
                10    3.3700000+01    4.2800000+01    7.1000000+00
                16    3.2900000+01    4.2900000+01    7.2000000+00
                22    3.3100000+01    4.3400000+01    8.0000000+00
                28    3.3300000+01    4.1700000+01    7.2000000+00
                34    3.2700000+01    4.2200000+01    8.4000000+00
   3.2983333+01 $YBAR   5.1544149-01 $SY   3.0375199+01 $LTLY
   4.2366667+01 $UBAR   8.2138694-01 $SU   3.8210449+01 $LTLU
   7.5166667+00 $EBAR   5.4558844-01 $SE

LABEL CM4-3, MIG-7106, 5356, 1.00 INCH 5 WEEKS
                 5    3.4400000+01    4.2400000+01    9.0000000+00
                11    3.3900000+01    4.3600000+01    7.4000000+00
                17    3.3400000+01    4.3000000+01    8.2000000+00
                23    3.4500000+01    4.2700000+01    7.6000000+00
                29    3.4100000+01    4.2700000+01    8.4000000+00
                35    3.4700000+01    4.2900000+01    8.4000000+00
   3.4166667+01 $YBAR   4.7188729-01 $SY   3.1778917+01 $LTLY
   4.2883333+01 $UBAR   4.0703800-01 $SU   4.0823721+01 $LTLU
   8.1666666+00 $EBAR   5.8537782-01 $SE

LABEL CM4-3, MIG-7106, 5356, 1.00 INCH 12 WEEKS
                 6    3.6400000+01    4.4500000+01    7.5000000+00
                12    3.7100000+01    4.4100000+01    7.5000000+00
                18    3.7100000+01    4.3900000+01    6.5000000+00
                24    3.7300000+01    4.4600000+01    7.0000000+00
                30    3.7200000+01    4.4000000+01    8.0000000+00
                36    3.6900000+01    4.4100000+01    6.5000000+00
   3.7000000+01 $YBAR   3.2250583-01 $SY   3.5368120+01 $LTLY
```

TABLE J-21.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY WELDMENTS

Panel No. CM5-4, 1.00-inch MIG/5556, Double V

```
       NUMBER              Y               U                 E
 LABEL CM5-4,M1G-7106,5556,1.00INCH,1 DAY
                 1   3.2200000+01    4.4700000+01    1.1500000+01
                 7   3.2500000+01    4.1300000+01               0
                13   3.2500000+01    4.4700000+01    1.0200000+01
                19   3.2400000+01    4.4100000+01    1.0200000+01
                25   3.2400000+01    4.5800000+01    1.1500000+01
                31   3.2500000+01    4.5000000+01    1.1500000+01
   3.2416667+01 $YBAR  1.1691374-01 $SY  3.1825083+01 $LTLY
   4.4266667+01 $UBAR  1.5552096+00 $SU  3.6397306+01 $LTLU
   1.0980000+01 $EBAR  7.1203930-01 $SE

 LABEL CM5-4,M1G-7106,5556,1.00INCH,4 DAY
                 2   3.4800000+01    4.1300000+01    9.7000000+00
                 8   3.5800000+01    4.4700000+01    8.8000000+00
                14   3.4800000+01    4.4400000+01    1.0000000+01
                20   3.4800000+01    4.7600000+01    1.1700000+01
                26   3.4800000+01    4.5000000+01    9.3000000+00
                32   3.5900000+01    4.3600000+01    1.0600000+01
   3.5150000+01 $YBAR  5.4314577-01 $SY  3.2401682+01 $LTLY
   4.4433333+01 $UBAR  2.0461383+00 $SU  3.4079873+01 $LTLU
   1.0016667+01 $EBAR  1.0264825+00 $SE

 LABEL CM5-4,M1G-7106,5556,1.00INCH,7 DAY
                 3   3.4900000+01    4.2700000+01    9.2000000+00
                 9   3.4900000+01    4.5600000+01    9.0000000+00
                15   3.4600000+01    4.4800000+01    8.0000000+00
                21   3.4700000+01    4.5500000+01    9.0000000+00
                27              0    4.5700000+01    9.0000000+00
                33   3.4700000+01    4.2600000+01    9.0000000+00
   3.4760000+01 $YBAR  1.3419831-01 $SY  3.3988360+01 $LTLY
   4.4483333+01 $UBAR  1.4552215+00 $SU  3.7119912+01 $LTLU
   8.8666666+00 $EBAR  4.3205006-01 $SE

 LABEL CM5-4,M1G-7106,5556,1.00INCH,2 WEEKS
                 4   3.4900000+01    4.3800000+01    8.0000000+00
                10   3.5400000+01    4.7300000+01    8.2000000+00
                16   3.5600000+01    4.5200000+01    8.9000000+00
                22   3.4900000+01    4.5400000+01    6.8000000+00
                28   3.5900000+01    4.5600000+01    7.5000000+00
                34   3.5300000+01    4.3900000+01    9.0000000+00
   3.5333333+01 $YBAR  3.9328392-01 $SY  3.3343317+01 $LTLY
   4.5200000+01 $UBAR  1.2852999+00 $SU  3.8696382+01 $LTLU
   8.0666667+00 $EBAR  8.3825215-01 $SE

 LABEL CM5-4, MIG-7106, 5556, 1.00 INCH 5 WEEKS
                 5   3.6100000+01    4.6500000+01    8.4000000+00
                11   3.6900000+01    4.6000000+01    7.7000000+00
                17   3.6500000+01    4.5000000+01    8.2000000+00
                23   3.6500000+01    4.5900000+01    9.9000000+00
                29   3.6200000+01    4.5900000+01    9.9000000+00
                35   3.6000000+01    4.3400000+01    8.9000000+00
   3.6366667+01 $YBAR  3.3267401-01 $SY  3.4683336+01 $LTLY
   4.5450000+01 $UBAR  1.1149015+00 $SU  3.9808598+01 $LTLU
   8.8333333+00 $EBAR  9.1140941-01 $SE

 LABEL CM5-4, MIG-7106, 5556, 1.00 INCH 12 WEEKS
                 6   3.8600000+01    4.2400000+01    7.5000000+00
                12   3.8700000+01    4.6700000+01    6.7000000+00
                18   3.9100000+01    4.6500000+01    7.2000000+00
                24   3.8900000+01    4.7000000+01    9.7000000+00
                30   3.8200000+01    4.5900000+01    9.2000000+00
                36   3.8300000+01    4.5300000+01    9.2000000+00
   3.8633333+01 $YBAR  3.4448607-01 $SY  3.6890234+01 $LTLY
   4.5633333+01 $UBAR  1.6966603+00 $SU  3.7048232+01 $LTLU
   8.2500000+00 $EBAR  1.2629333+00 $SE
```

TABLE J-22.

UNIAXIAL TENSILE TEST RESULTS ON X7106-T63 ALUMINUM ALLOY PARENT METAL

```
       NUMBER              Y               U                 E
 LABEL PARENT METAL, 7106, .187 INCH
                 1   6.1000000+01    6.7800000+01    1.1200000+01
                 2   6.1300000+01    6.8300000+01    1.0000000+01
                 3   6.0700000+01    6.7800000+01    1.1000000+01
                 4   6.0900000+01    6.7800000+01    1.1200000+01
                 5   6.1000000+01    6.8100000+01    1.1100000+01
   6.0980000+01 $YBAR  2.1678808-01 $SY  5.9733468+01 $LTLY
   6.7960000+01 $UBAR  2.3027004-01 $SU  6.6635947+01 $LTLU
   1.0900000+01 $EBAR  5.0990218-01 $SE

 LABEL PARENT METAL, 7106, .500 INCH
                 1   5.9000000+01    6.4600000+01    1.7700000+01
                 2   6.0100000+01    6.5800000+01    1.7800000+01
                 3   5.8500000+01    6.4400000+01    1.7800000+01
                 4   5.9100000+01    6.5000000+01    1.7800000+01
                 5   5.8800000+01    6.4800000+01    1.7500000+01
   5.9100000+01 $YBAR  6.0414422-01 $SY  5.5626171+01 $LTLY
   6.4920000+01 $UBAR  5.4036301-01 $SU  6.1812912+01 $LTLU
   1.7720000+01 $EBAR  1.3038847-01 $SE

 LABEL PARENT METAL, 71.6, 1.00 INCH
                 1   5.8100000+01    6.4100000+01    2.0700000+01
                 2   5.8400000+01    6.4500000+01    2.0900000+01
                 3   5.7900000+01    6.4000000+01    2.0900000+01
                 4   5.8800000+01    6.4900000+01    2.0700000+01
                 5   5.8400000+01    6.4300000+01    2.0500000+01
   5.8320000+01 $YBAR  3.4210366-01 $SY  5.6352904+01 $LTLY
   6.4360000+01 $UBAR  3.5777924-01 $SU  6.2302769+01 $LTLU
   2.0740000+01 $EBAR  1.6733164-01 $SE
```

Notes: (1) Tensile axis normal to rolling direction.

(2) Data taken from tests conducted under Contract NAS8-1529, Mod 6 (4th year).

APPENDIX K

STATISTICAL ANALYSIS OF TEST DATA

STATISTICAL ANALYSIS OF TEST DATA

The data from the uniaxial tensile tests and hydraulic bulge tests were analyzed statistically to establish minimum strength values with a specified degree of confidence. The analysis was based on the "Tolerance Limit Theory" assuming that the data conform to a normal distribution curve.

In the analysis of the data, the mean value, standard deviation and lower tolerance limit were computed for each property. The lower tolerance limit (LTL) was selected such that 99% of the individual values of the variable property are above the limit 95% of the time. The computations were carried out by the procedures indicated below:

$$\bar{x} = \frac{x_i}{N} = \text{mean value}$$

where

x_i = individual value

N = number of tests

$$S = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{N - 1}} = \text{Standard deviation}$$

$$LTL = \bar{x} - KS = \text{lower tolerance limit}$$

where K is a factor statistically computed for a 99% LTL with 95% confidence. K factors for sample sizes up to 50 are listed in the following table:

Sample Size	K Factor	Sample Size	K Factor	Sample Size	K Factor
5	5.75	15	3.52	25	3.15
6	5.06	16	3.46	26	3.13
7	4.64	17	3.42	27	3.11
8	4.35	18	3.37	28	3.09
9	4.14	19	3.33	29	3.07
10	3.98	20	3.29	30	3.06
11	3.85	21	3.26	35	2.99
12	3.74	22	3.23	40	2.94
13	3.66	23	3.21	45	2.90
14	3.58	24	3.18	50	2.86

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