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HUNTSVILLE, ALABAMA

(NASA TMX 50837;

EVALUATION OF WELDED 2219-T87 ALUMINUM ALLOY

by

Richard A. Davis

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ABSTRACT

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A program to determine weld strength design allowables and other welding information for aluminum alloy 2219-T87 is reported herein. This program was conducted in support of the Saturn S-IC.

Metal arc, inert gas shielded (MIG) welds and tungsten arc, inert gas shielded (TIG) welds were evaluated in plate thicknesses of 1/4, 1/2, 3/4, and 1-inch for aluminum alloy 2219-T87. Welds, by each process and in each thickness, were produced in the flat, vertical and horizontal welding positions. Plate, 2-inches thick, was welded by each process in the flat position only.

Studies were conducted to determine the extent of weld heat affected zone into the base metal. A value of 1-3/8 inches from the centerline of the weld is given as a maximum extent of heat affected zone, if proper joint design and welding process are employed.

Ultimate strength data of welds were statistically analyzed by Students' "t" test, assuming the data conformed to a normal distribution. Both 95 and 99 percent confidence levels were determined for TIG welds, MIG welds, and the combined MIG and TIG welds. TIG welds were more consistent in strength, slightly higher in ultimate strength values, and exhibited better weld quality (more sound) than MIG welds.

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By

Richard A. Davis

ENGINEERING MATERIALS BRANCH
PROPULSION AND VEHICLE ENGINEERING DIVISION

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by
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SUMMARY

A program to determine weld strength design allowables and other welding information for aluminum alloy 2219-T87 is reported herein. This program was conducted in support of the Saturn S-IC.

Metal arc, inert gas shielded (MIG) welds and tungsten arc, inert gas shielded (TIG) welds were evaluated in plate thicknesses of 1/4, 1/2, 3/4, and 1-inch. Welds by each process and in each thickness were produced in the flat, vertical, and horizontal welding positions. Plate, 2-inches thick, was welded by each process in the flat position only.

The extent of weld heat affected zone into the base metal was studied. A value of 1-3/8 inches from the centerline of the weld was determined as a maximum extent of the heat affected zone, if proper joint design and welding process are employed.

Ultimate strength data for welds were analyzed statistically by Students' "t" test, assuming the data conformed to a normal distribution. A weld strength design allowable of 35 Kpsi for thicknesses to and including 1-inch was established with a 99 percent confidence level and 99.3 percent conformance. TIG welds had more consistent strength values, slightly higher ultimate strength and better weld quality than MIG welds.

Evaluation of defects which were revealed by radiographic inspection resulted in establishment of radiographic standards for acceptance of welds in aluminum alloy plate. Moreover, it was disclosed that radiography might not detect a lack-of-penetration in welds which are welded from two sides. The latter must be controlled by visual inspection during process operations.

INTRODUCTION

The welding of high strength aluminum alloys in heavy plate thicknesses has been a major objective for the past 18 months. At the outset, several high strength aluminum alloys were being considered for use in the construction of future space vehicles. During this time, the major welding effort was devoted to the aluminum alloy 2014 and 5456. Aluminum alloy 2219 became a candidate for construction of the Saturn S-IC late in 1961, and eventually was chosen as the major structural alloy for this stage. (Ref. 1)

The ground rules established for weldability investigations were that 2219-T87 would be used and that full post weld heat treatments would not be feasible. Therefore, all weld evaluations would be based on the "as welded condition." Moreover, welding would be conducted in the flat, vertical, and horizontal welding positions utilizing both the MIG and TIG welding processes.

It was evident from the preliminary weldability investigations that welding equipment with very precise controls would be necessary to ensure good welds. The power sources and controls which proved best for this application cost approximately ten times that of previously acceptable equipment.

Tooling for horizontal and vertical welding was a very important part of the welding development studies. Methods Research and Development Branch and Fabrication Engineering Branch of Manufacturing Engineering Division were responsible for the major developments in this area, which resulted in the so called "Paddle Wheel" fixture depicted in FIG 1. This particular type of tooling is proposed for production welding of the S-IC tankage.

In May, 1962, weld strength design allowables for 2219-T87 plate were requested for the Saturn S-IC. All available data from within MSFC and outside organizations were collected and analyzed. These data were not only insufficient in amount, but the history of welding conditions, e.g. joint design, filler metal, and weld quality standard were not available from the various sources. Recognizing the incompleteness of these data, the following preliminary values of weld strength design allowables were issued by this Branch:

Plate Thicknesses to 1" - 35 Kpsi ultimate strength.

Plate Thicknesses 1" to 2" - 30 Kpsi ultimate strength.

Subsequently, a program was initiated to confirm these values.

EQUIPMENT AND PROCEDURES

Welding Processes

Both the metal arc, inert gas shielded (MIG), and tungsten arc, inert gas shielded (TIG) welding processes were utilized for this program. MIG welding, as depicted in FIG 2(a), is a consumable electrode process; that is, the welding arc is maintained between the filler metal (electrode) and the work piece,with the filler metal being transferred through the arc to the work piece. In contrast to this, TIG welding, FIG 2(b), is a nonconsumable electrode process wherein the filler metal (electrically neutral) is introduced from a source which is not part of the basic electric welding circuit. In the latter process, the electric arc is maintained between a tungsten electrode and the work piece.

Welding Positions

Welding by both the MIG and TIG processes was accomplished in the flat, vertical,and horizontal positions. As illustrated in FIG 3, flat position welding is done with the work piece in a horizontal plane and the torch in a vertical position with the torch travel in a horizontal direction; vertical position welding is done with the work piece in a vertical plane and the torch in a horizontal position with torch movement in a vertical direction; horizontal welding is done with the work piece in a vertical plane and the torch in a horizontal position with torch movement in a horizontal direction. FIG 4 shows a laboratory set-up within the Manufacturing Engineering Division for producing welds in the horizontal position.

Material Thicknesses

Aluminum alloy 2219-T87, in plate thicknesses of 1/4, 1/2, 3/4, and 1-inch, was welded by both the MIG and TIG processes in each welding position, using 2319 aluminum alloy filler metal. Because of a limited amount of material available, plate of 2-inch thickness was welded in the flat position only, using a TIG root pass with subsequent passes by the MIG process.

Joint Designs

Various weld joint designs were utilized for each thickness of material as shown in FIG 5. Initially, one joint design was selected for each welding process in each thickness, but this was found to be inadequate for the horizontal and vertical welding positions.

Practical Design Problem

FIG 6(a) depicts a typical design problem wherein the configuration is comprised of an integral thin skin, beefed-up weld pad,and reinforcing Tee member. The configuration is milled from 2-inch thick plate. The design engineer must know the properties of incremental thicknesses through the 2-inch plate and the properties of the welded surface segment. An investigation was made to determine if segmental thicknesses of 2-inch plate react similarly to equal thickness of rolled plate. Tensile specimens (base metal) were obtained from increments of the 2-inch plate as shown in FIG 6(b). For weld evaluation, panels 4" x 24" x 2-inch thick were sawed to form two-panels 4" x 24" x 1-inch thick. The saw cut surface was machined to result in panels 4" x 24" x 3/4-inch thick. Both MIG weld and TIG weld properties were evaluated for the latter panels.

Weld Preparation and Inspection

Following the machining of the weld joint, and immediately prior to welding, each weld joint was scraped to remove all oxides and other foreign matter. Each weld pass, in multi-pass welding, was cleaned and inspected visually prior to depositing subsequent passes. Several panels, as typified by FIG 2(a), were welded for each material thickness, by each process and in each welding position. After completion of the weld, each panel was radiographically examined. Since there was no radiographic standard of acceptance limits for thicknesses above 1/4-inch, each panel was inspected for types of defects, later to be used in determining standards.

TESTING AND RESULTS

Uniaxial tensile specimens and weld cross-sections for macroscopic and microscopic examination were obtained from each weld panel. Following mechanical testing, the tensile strength and fractured surface of each specimen was correlated with the weld quality revealed by radiographic examination. From observation of the fractured surface of specimens, it was found that porosity, having a total linear dimension of approximately 1% of the thickness in the thickness direction, is readily detectable by radiography. Acceptable limits of porosity were based on the strength of the weld. That is, if a specimen contained porosity or inclusions of a degree to reduce weld strength appreciably below the group strength, the defects were considered unacceptable, and this information was used to establish a defect limit. All other specimens containing this amount of porosity or other inclusions were discarded as unacceptable welds and not reported in the strength analysis. Micro porosity, not detectable by radiography, also affects the weld strength. An example of this porosity, which is found in MIG welds more often than in TIG welds, is shown in FIG 7.

Lack-of-penetration, as shown in FIG 8, is a type of defect not detectable by radiography. In one such sample, the width of the unfused land measured .0002-inch wide at the widest point, while at the other extreme, as exemplified in FIG 8, the width is near grain boundary size. In this incidence, grains have actually grown across the unpenetrated line. With defects of this order of magnitude, radiography is useless and other means of inspection will be necessary. Ultrasonic inspection can detect defects the size of grain boundaries, but in this case, it would be difficult to differentiate between grain boundaries and the unpenetrated line. In-process control, using visual inspection of the root pass to ensure proper penetration prior to welding the other side, is one method of controlling lack-of-penetration. Another method would be to deposit the first root pass, then "back chip" the other side to sound metal prior to further welding. When welding from one side only, the root penetration should always be visible, and this eliminates the problem. This lack-of-penetration occurred only occasionally in TIG welds, while it was a frequent occurrence in MIG welds.

With reference to FIG 9, curve A presents the mean ultimate strength of base metal. All mechanical testing was done at room temperature. The data represented by curve B include both MIG and TIG welds in the flat, horizontal, and vertical welding positions, utilizing the narrow width reduced section tensile specimen, as indicated. This tensile specimen configuration was utilized in an earlier program wherein a machine with only 10,000 pounds capacity was available for cryogenic testing. Since tooling existed for machining this configuration, it was the obvious choice for this program. As mechanical testing progressed, it was noted that small weld defects, such as porosity and inclusions, were reducing the weld strength and resulting in excessive scatter of values. Other stress factors may be involved here, but the most obvious factor was the reduction in area caused by a weld defect in the narrow specimen (rectangular cross-section) versus the same defect in square cross-section. (A "square cross-section" describes a tensile specimen having a reduced section width equal to the thickness.)

For simplicity of machining, specimen configuration C was selected to evaluate this phenomenon, recognizing that the failures would occur in the area of the weld rather than in the tensile machine grips. The results of these tests are shown by curve C where it can be seen that not less than 2000 psi mean ultimate strength is gained over the narrow specimen. This, of course, is more nearly representative of structural components than the narrow specimen. Perhaps values even more representative of structural components may be obtained by further increasing the width of the specimen.

By the time the influence of specimen configuration on tensile strength was discovered, it was too late to modify the total program. However, from several panels not yet machined, specimen configurations B and C were selected alternately throughout each panel as a means of making strength comparisons. The data from curve C are not reflected in the statistical analysis presented later in this report.

With an initial goal of approximately 200 specimens for each thickness, there was some sacrifice in curve B for thicknesses 1/2-inch and above in order to obtain values for curve C. The number of specimens tested for each point are listed in parenthesis beside the point.

To obtain the advantages of a reduced section tensile specimen, tooling for machining specimen configuration D was manufactured immediately for use in future testing. This configuration has the width of weld equal to the thickness of the material. The post-program data,also shown in FIG 9,were obtained from specimens of this configuration.

Upon completion of mechanical testing and evaluation of weld quality, it was concluded that additional specimens would be required in order to justify the discarding of those specimens exhibiting lack of penetration. These were designated as "quality assurance specimens," wherein the objective was to prove that lack-of-penetration could be controlled by proper welding and inspection techniques. (Ref. 2) Since 3/4-inch plate exhibited the most lack-of-penetration defects, it was the thickness chosen for this phase. Panels were welded by the TIG process and MIG process with a TIG root pass. Welding was conducted in the flat and horizontal positions by each process. A total of 254 specimens was tensile tested for an overall average of 43.9 Kpsi ultimate tensile strength (shown in FIG 9). The results of the quality assurance evaluation indicate that not only can lack-of-penetration be controlled, but also other defects are minimized by using proper cleaning between weld passes.

To indicate that production welds are equal to those produced by laboratory techniques, Manufacturing Engineering Division furnished welds produced by the TIG process (two weld passes from one side only) in the horizontal position. These welds, in 1/2-inch plate, were produced on the "Paddle Wheel" fixture shown in FIG 1. A square butt joint design was employed with the TIG process, the first pass being only a fusion pass. Filler metal was added on the second pass. A total of 12 specimens was tensile tested, and the average tensile strength value is shown in FIG 9.

The feasibility of weld repairs was studied. The joint design employed for this study was a double "V", 60° included angle, with a 1/8-inch land. Welding was done by both the MIG and TIG processes in the vertical weld position. After completion of the initial weld, three tensile specimens according to configuration D were removed; the weld in the remainder of the panel was machined out on both sides, leaving the 1/8-inch land intact. The panel was re-welded by the MIG or TIG process (mechanized), corresponding to the initial weld, and designated as "repair No. 1." Again, three tensile specimens were removed; the weld in the remainder of the panel was machined out, as before, and subsequently re-welded and designated "repair No. 2." This procedure was again employed for a third repair.

There was no loss in strength by either the MIG or the TIG process from the initial weld through the third repair and no significant difference in metallurgical structure of the weld or adjacent area. The results of mechanical testing are shown in FIG 9 as a single value of mean ultimate tensile strength which includes the first, second, and third weld repair values. Again, it should be noted that this is only a feasibility study and that all avenues of weld repair were not explored. A program is now being conducted which should yield more definitive information.

FIG 10 presents the average ultimate strength values of TIG and MIG welds for the flat, horizontal, and vertical welding positions. These values were obtained from the same data as curve B, FIG 9. It is apparent that vertical and horizontal welds are higher in strength than flat welds of 3/4-inch and 1-inch thicknesses. This difference is attributed to the joint design and number of weld passes utilized. Whereas welding in the flat position allows larger and fewer weld passes, the vertical and horizontal welds require small weld passes. This led to exploration of weld joint designs for the vertical and horizontal welding positions which resulted in the design (i) and (k) of FIG 5. The weld configuration resulting from this joint design in one-inch plate, welded by the TIG process in the horizontal position, is shown in FIG 11(a). In contrast, FIG 11(b) depicts a TIG weld in one-inch plate produced in the flat position using joint design (j) of FIG 5. Welds, of the quality required for primary structures, can be produced regardless of position; however, more care must be exercised when welding in the horizontal position to avoid excessive porosity.

FIG 12 shows again curve B of FIG 9 and, for comparison, the mean ultimate strength of those welds containing lack-of-penetration. This illustrates the necessity for good quality control to eliminate the lack-of-penetration defect when welding from both sides.

Cross-sectioned welds, as illustrated by the sketch in FIG 13 were obtained from each variable of joint design, welding process, welding position, and material thickness. Included therein is a typical hardness traverse through the weld cross-section with the corresponding hardness values plotted above. Hardness measurements were taken at 1/8-inch increments from centerline of the weld in order to determine the extent of the heat affected zone into the base metal. The results of this study revealed that: (1) TIG welds have wider heat affected zones than MIG welds; (2) joint designs requiring more filler metal have wider heat affected zones; and (3) tooling, which provides a heat sink, reduces the width of the heat affected zone.

The hardness measurements shown in FIG 13 were obtained from a panel of one-inch plate, TIG welded in the flat position utilizing a double "V", 60° included angle joint design. This specimen had the widest heat affected zone (approximately 1-3/8 inches from the weld centerline) of all the specimens from the varied conditions evaluated. In design for welding, consideration should be given to a possible weld repair at the fusion line of the initial weld. This type of repair could cause considerable increase in the extent of the heat affect zone into the base metal.

Statistical Analysis of Weld Strength Data

In analyzing the weld strength data, it was assumed that the data conformed to a normal distribution curve, as illustrated by FIG 14. Weld strength confidence levels, as the term is used herein, refers to a level of probability from which one might predict the strength of a weld based on previous test values. The normal distribution analysis takes the scatter of test values, of a sample number, into consideration and predicts, for the total population of all values in existence, a frequency of occurrence of a certain value. For example, if data having a large scatter of test values were to be analyzed at a 99 percent confidence level, the resultant value may be of a magnitude not encountered in the actual test values. This would mean that, based on the scatter of data and number of test values, the analysis predicts there may be occurrences of values of that magnitude even though they were not previously encountered in the actual test values.

The normal distribution curve has two ends, one for high values and one for low values. Since the concern here is to establish minimum strength values, we deal only with one side of the curve which is called a single tailed test. The value of Mx is the arithmetic average (mean), and σx is the standard deviation of the population, which is a measure of the scatter of test values. A given confidence level is determined by the area encompassed by the curve, within the limits of the desired confidence level. Thus, a 99 percent confidence level encompasses 99 percent of the area under the curve; the 1% discarded is at one end of the curve (low strength side). To obtain the confidence level, the percentile value (t_{cl}) is multiplied by σx, the product of which is substracted from Mx.

Once a given confidence level is determined, the data are then analyzed for conformance to the confidence level. Conformance is the ratio of values equal to, or greater than, the confidence level value-to the number of values in the test expressed in percentage.

FIG 15 shows ultimate strength values at 99 and 95 percent confidence levels for plate thicknesses 1/4, 1/2, 3/4, and 1-inch. For each thickness, the variables of welding process and welding position are combined to obtain the given value.

Table I presents the statistical analysis of all MIG welds, all TIG welds, and the combination of MIG and TIG welds. Here, N is the number of specimens or population; MX, σx, etc. are as previously defined. Note the difference in magnitude of σx between TIG welds and MIG welds. This means that TIG welds were more consistent in strength. The TIG welds were also slightly higher in ultimate strength than MIG welds.

FIG 16 lists the results of tests to determine strength variation through the thickness of 2-inch plate. These results were obtained from segments, approximately 0.220-inch thick,(Refer to FIG 6(b)) taken through the plate.

Table II presents the data obtained from welded 2-inch plate. These welds were produced in the flat position by the MIG process using a TIG root pass. Only a small amount of material was available in this thickness, therefore, neither optimum joint design or welding technique was developed. The resulting data should be considered preliminary and not final.

Listed in Table IIIare data comparing welded 3/4-inch surface segments of 2-inch plate and welded 3/4-inch thick mill (as-rolled) material. (Refer to FIG 6(a)) These data indicate that 3/4-inch surface segments of 2-inch plate can be welded by the TIG or MIG process to result in strength equivalent to those of a standard as-rolled plate thickness.

CONCLUSIONS

The results of these tests suggest that for aluminum alloy 2219-T87 in thicknesses 1/4-inch through 2-inches, welding can be accomplished equally well in the flat, horizontal, or vertical position by the MIG or TIG process. However, the TIG welds had better weld quality, more consistent strength values, and higher ultimate strength. Structural quality welds can be obtained in these plate thicknesses, but will require more manufacturing processes and inspection operations than have been used in the past with plate or sheet thicknesses of 1/4-inch or below. The use of proper joint design results in better weld quality and higher mechanical properties. Weld strength data, from plate thicknesses through 1-inch, for both MIG and TIG welds in the flat, horizontal, and vertical positions were analyzed statistically. This analysis confirmed the ultimate strength design allowable of 35 Kpsi (issued in May 1962) with better than a 99 percent confidence level and 99.3 percent conformance. Results of the weld repair feasibility study indicate there was no loss in ultimate strength as a result of three successive weld repairs in 3/4-inch thick plate. Tests are presently being conducted for a complete evaluation.

The extent of the heat affected zone into the base metal is a function of welding process, width of cast structure and heat sink (tooling and material thickness). The width of cast structure might be extended beyond that intended by the original joint design by weld repairs.

The ultimate strength of welds in a 3/4-inch surface segment of 2-inch plate may be correlated on an equal basis to welds in 3/4-inch mill material.

REFERENCES

1. C. E. Cataldo, "Weldability Studies of 5456-H343 and 2219-T87 Aluminum Alloy Plates," IN-P&VE-M-62-2.
2. H. L. Gilmore, "Weld Quality Assurance Program" MSFC Report to be issued early 1963.

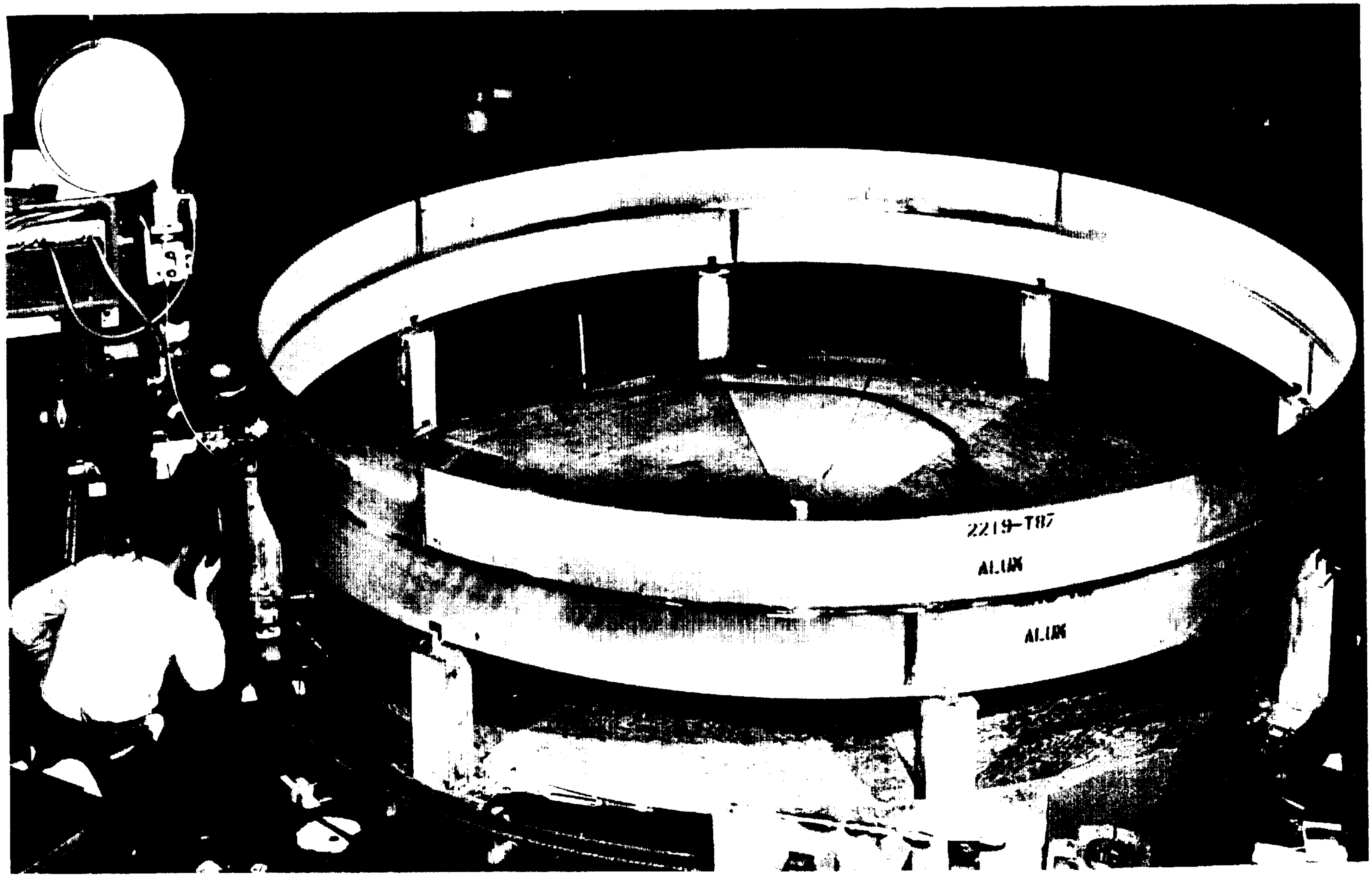

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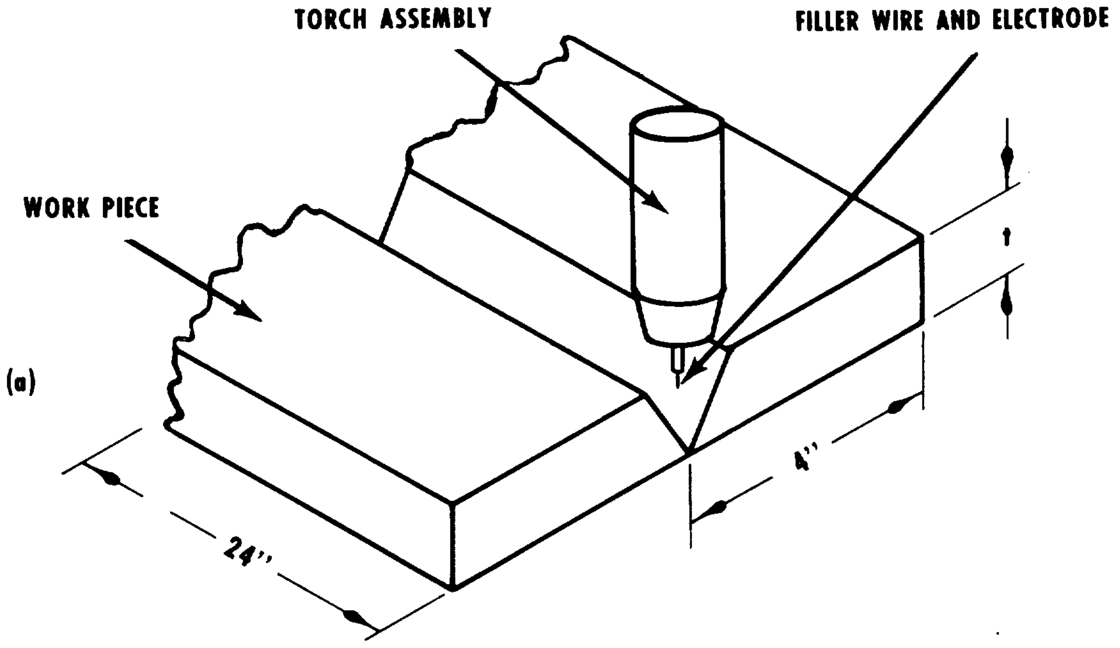
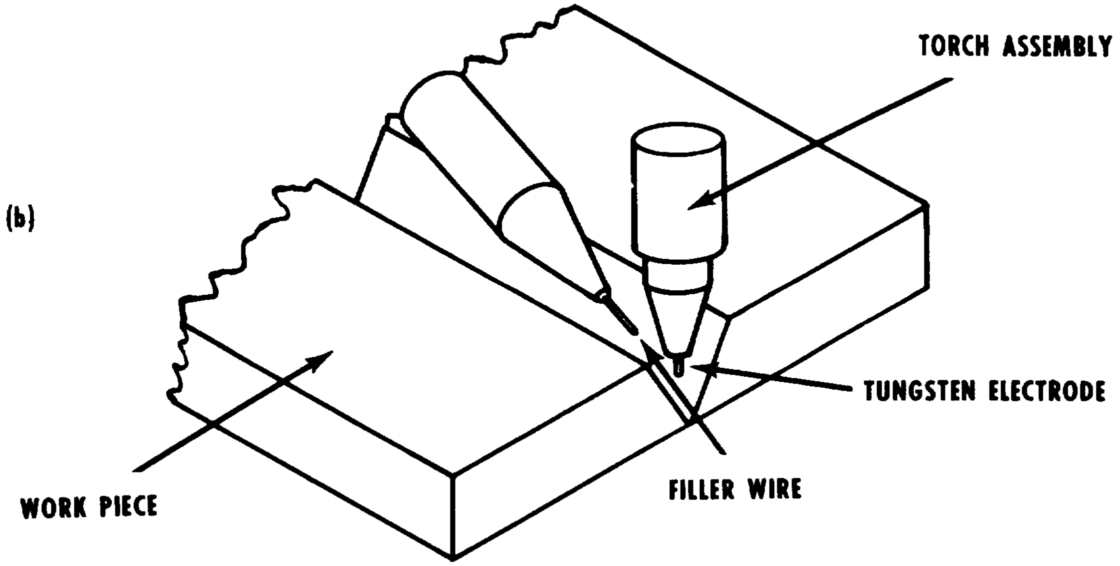
FIGURE 1 PRODUCTION WELD TEST SETUP FOR WELDING 105 INCH DIAMETER TANKS USING "PADDLE WHEEL" FIXTURE



MIG
METAL ARC, INERT GAS SHIELDED
(CONSUMABLE ELECTRODE)



TIG
TUNGSTEN ARC, INERT GAS SHIELDED
(NON-CONSUMABLE ELECTRODE)

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FIGURE 2 SCHEMATIC OF MIG AND TIG WELDING PROCESSES

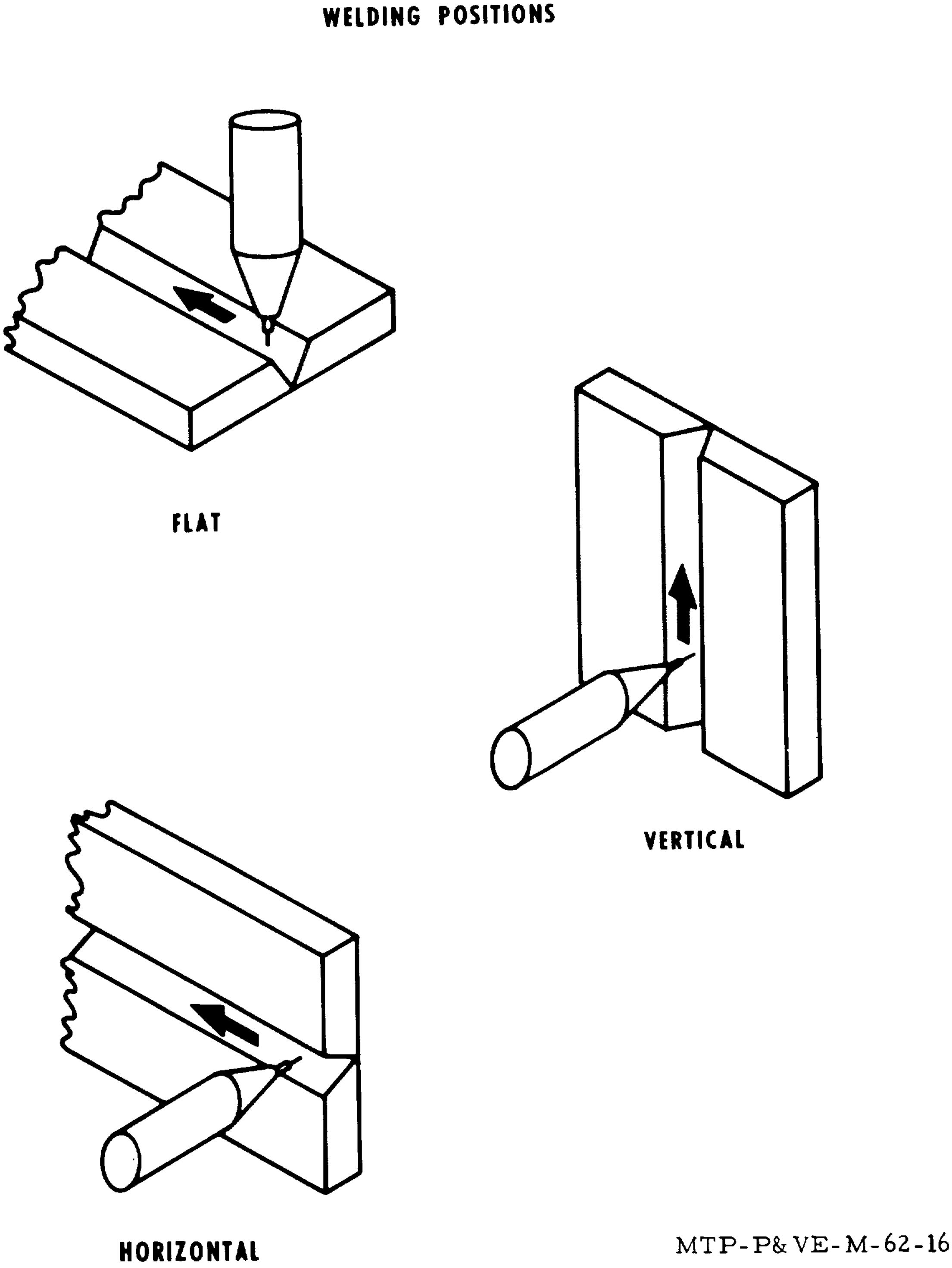

FIGURE 3 SCHEMATIC OF WELDING POSITIONS

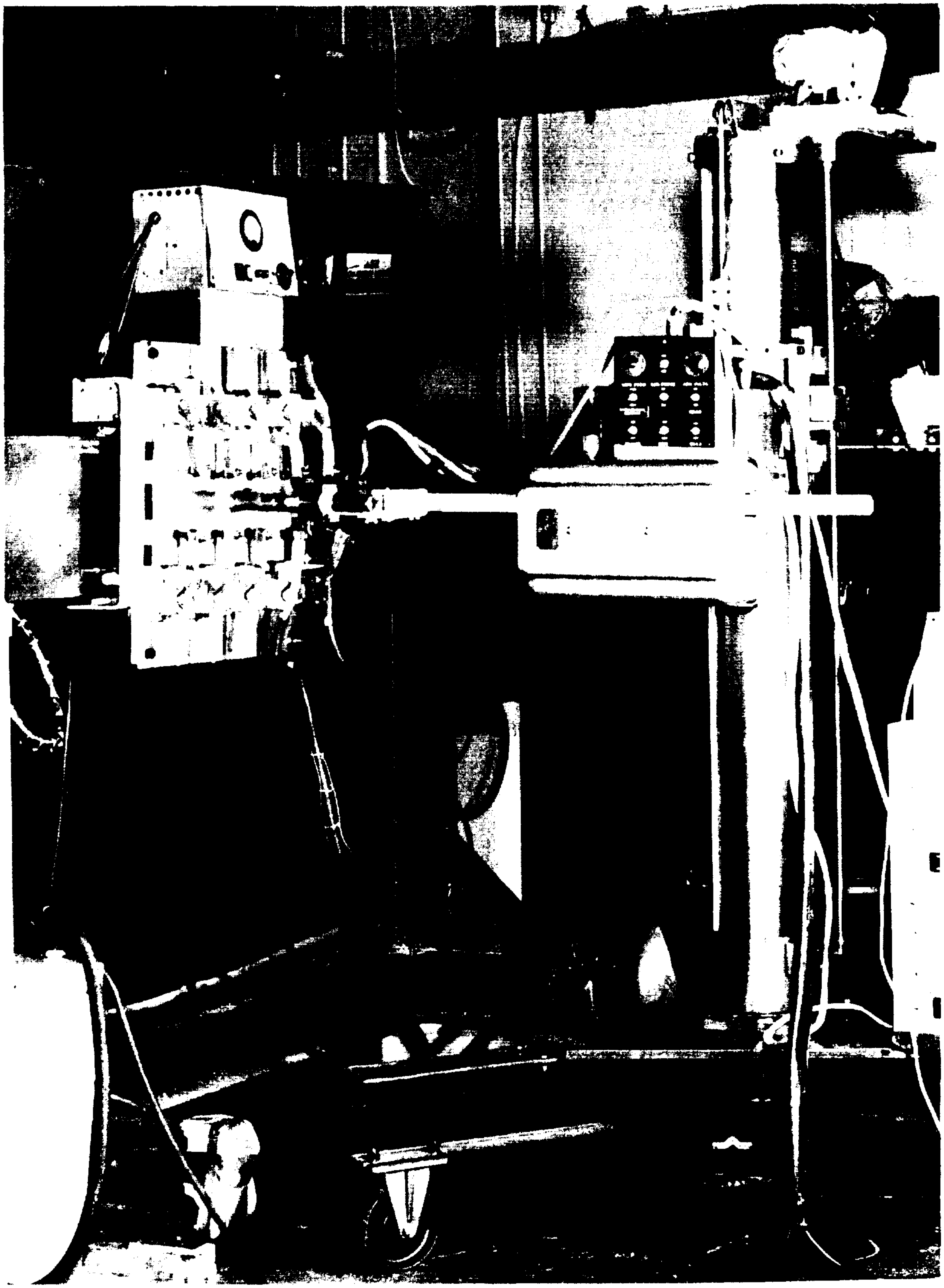

FIGURE 4 TYPICAL LABORATORY SETUP FOR HORIZONTAL WELDING

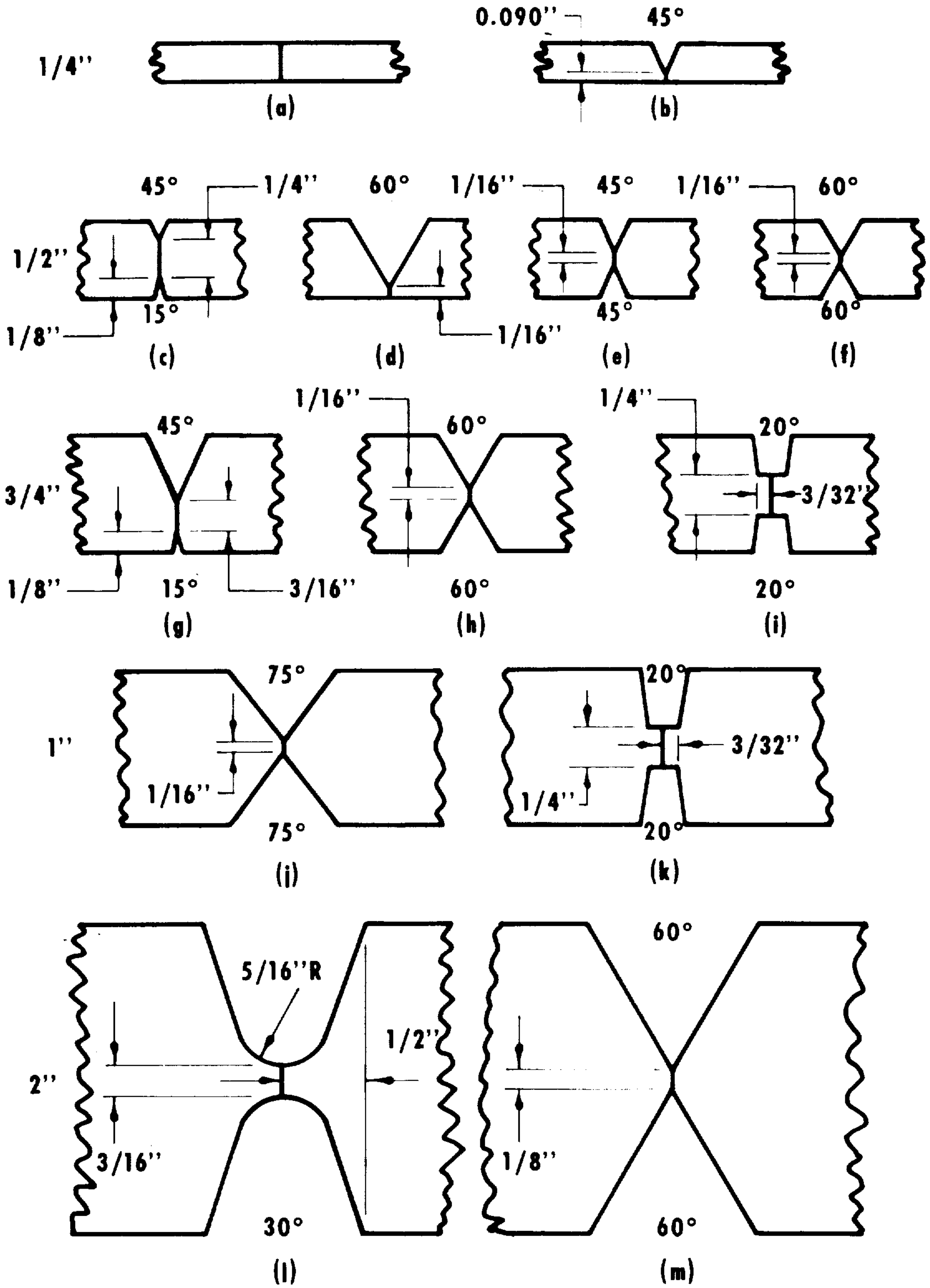

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FIGURE 5 WELD JOINT DESIGNS

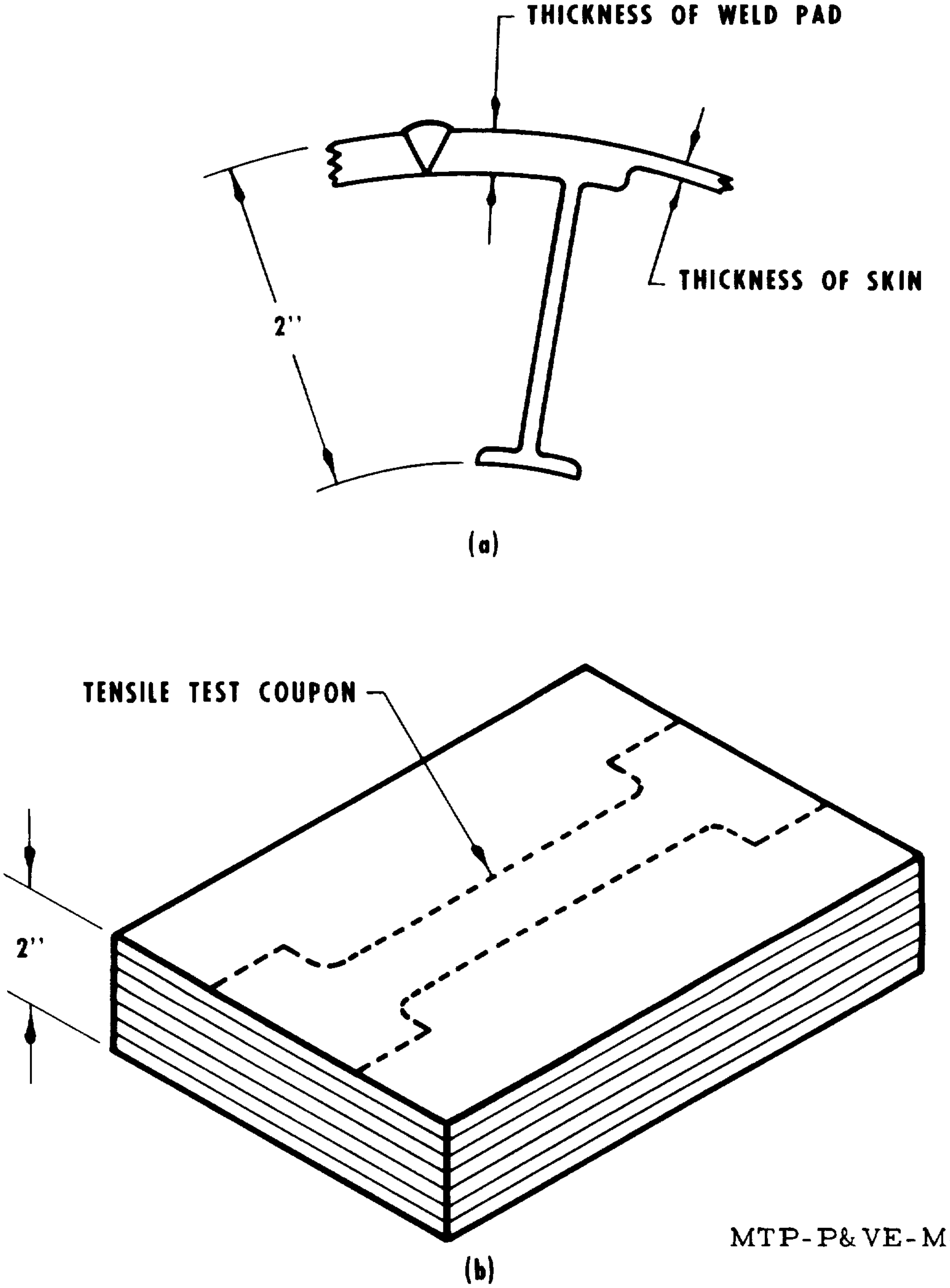

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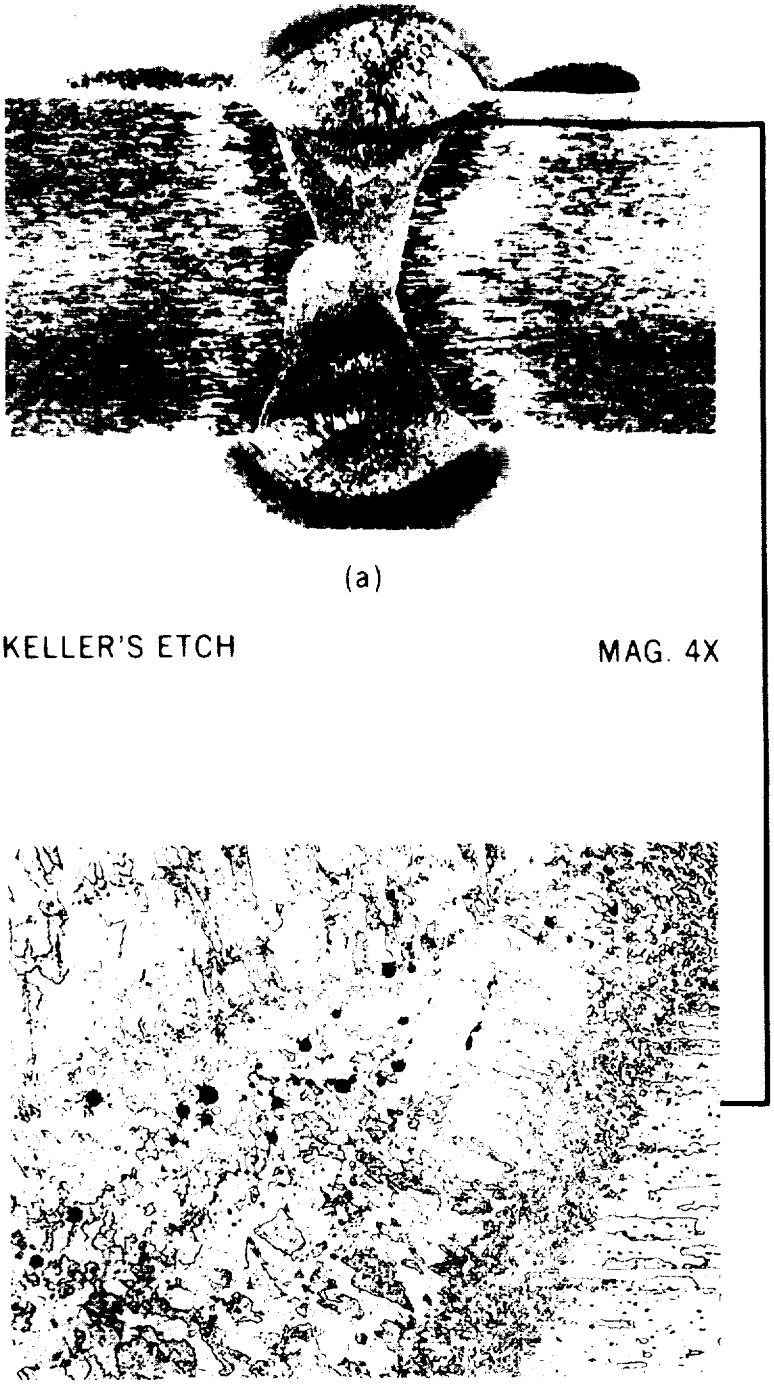
FIGURE 6 (a) CONFIGURATION OF TRANSVERSE SECTION OF TANKS USED IN SATURN S1-C, C-5 BOOSTER (b) LOCATION OF TENSILE TEST COUPONS REMOVED FROM TWO INCH BASE PLATE



(a)

KELLER'S ETCH MAG. 4X

(b)

KELLER'S ETCH MAG. 50X

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FIGURE 7 (a) MIG WELD IN 1/2 INCH PLATE (2219-T87)
(b) MICRO-POROSITY LOCATED WITHIN THE FUSION ZONE

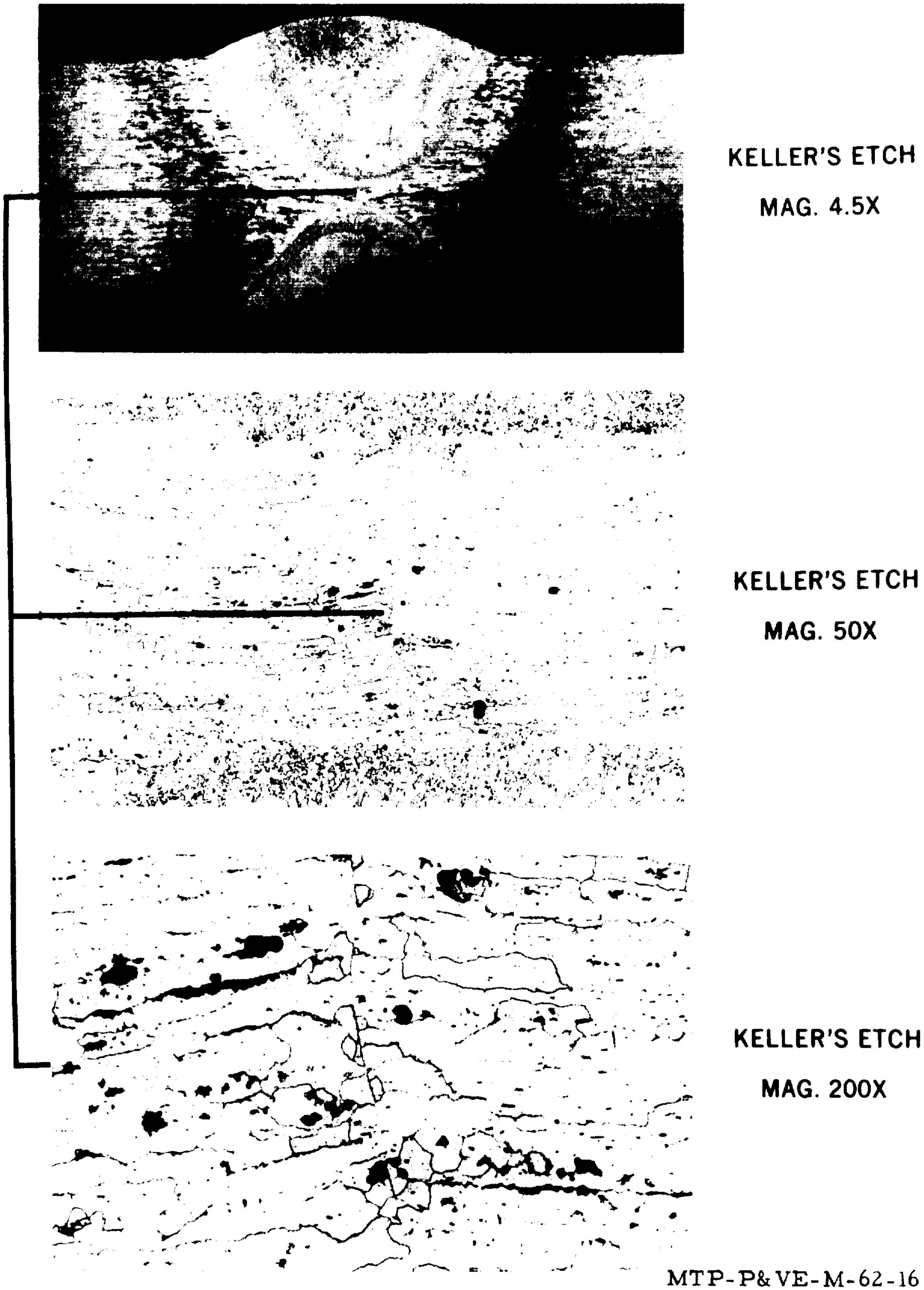
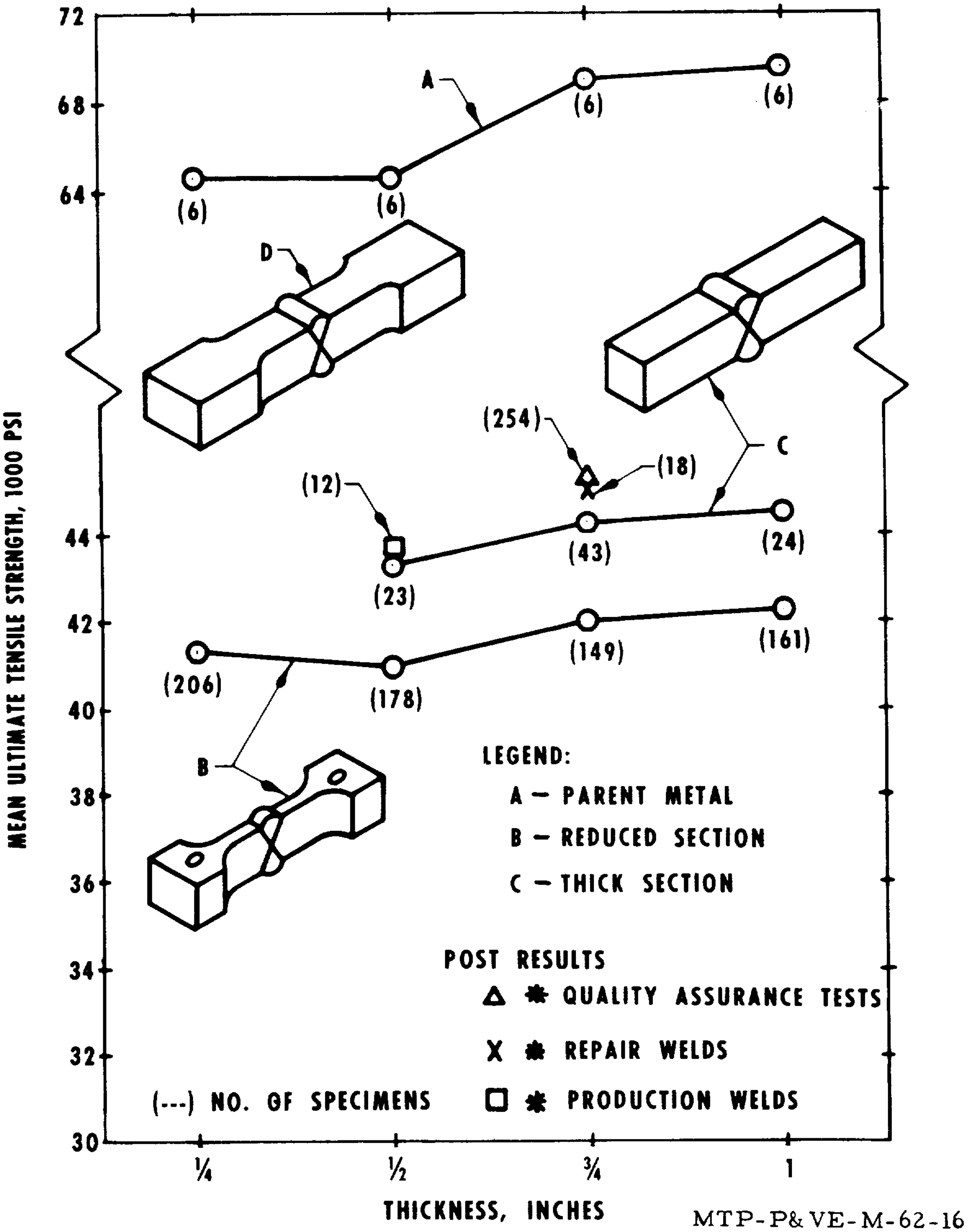


FIGURE 8 WELD CROSS-SECTION ILLUSTRATING LACK OF PENETRATION



* DATA OBTAINED USING SPECIMEN CONFIGURATION D

FIGURE 9 MEAN ULTIMATE TENSILE STRENGTH OF BASE METAL AND WELDED SPECIMENS (2219-T87 ALUMINUM ALLOY)

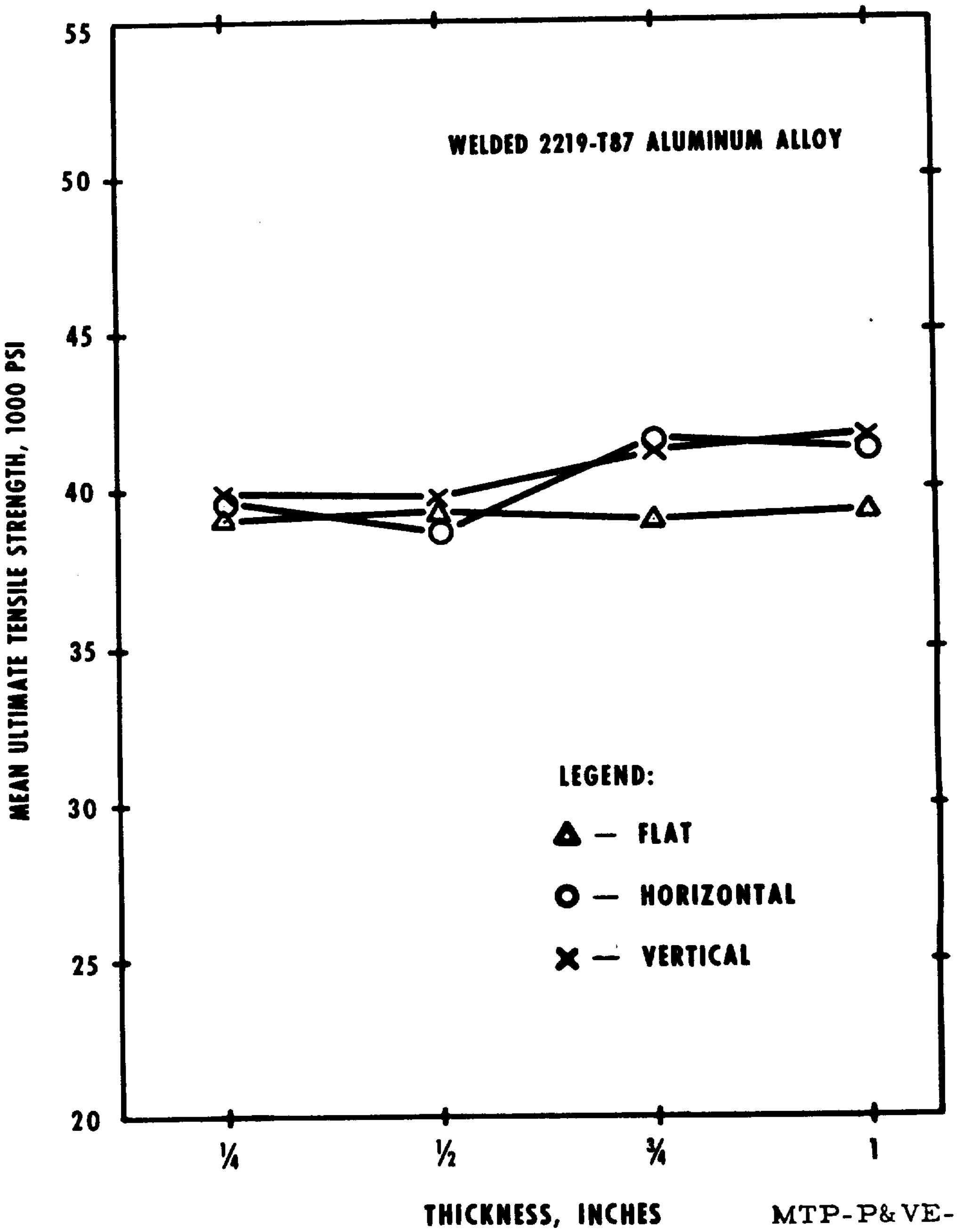


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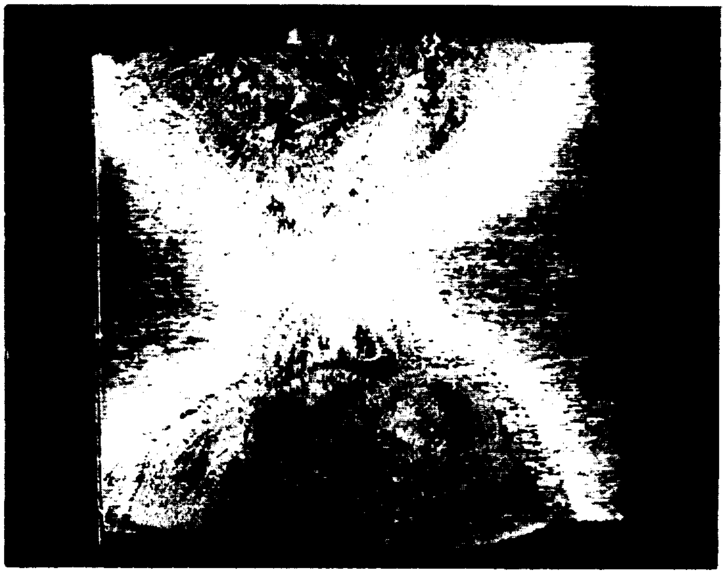
FIGURE 10 MEAN ULTIMATE TENSILE STRENGTH OF WELDS PRODUCED IN THE FLAT, VERTICAL AND HORIZONTAL WELDING POSITIONS

(a) JOINT DESIGN K

KELLER'S ETCH MAG. 2.75X



(b) JOINT DESIGN J

KELLER'S ETCH MAG. 2.75X

FIGURE 11 COMPARISON OF WELDS RESULTING FROM JOINT DESIGNS J AND K OF FIGURE 5

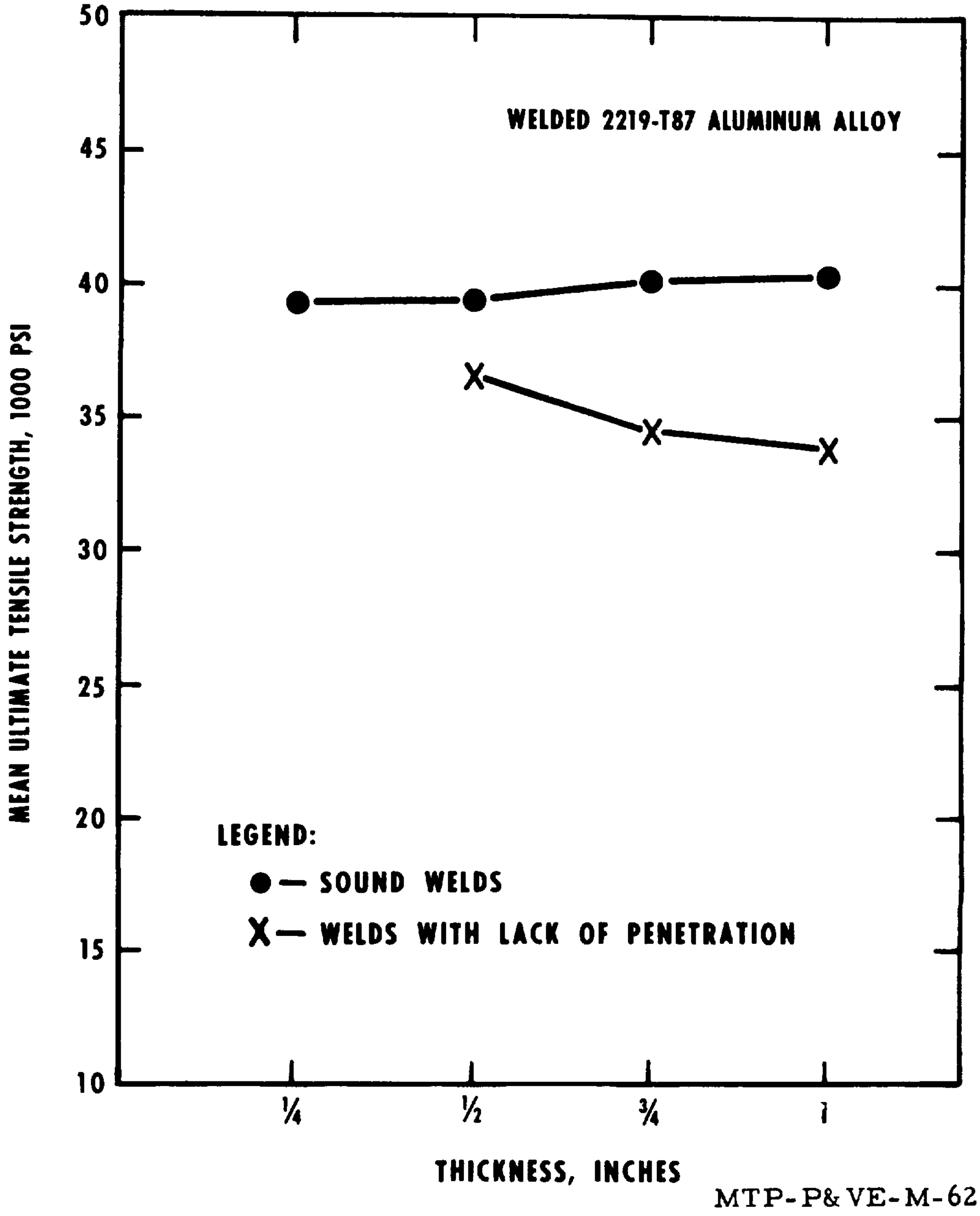


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FIGURE 12 LOSS IN WELD STRENGTH RESULTING FROM LACK OF PENETRATION

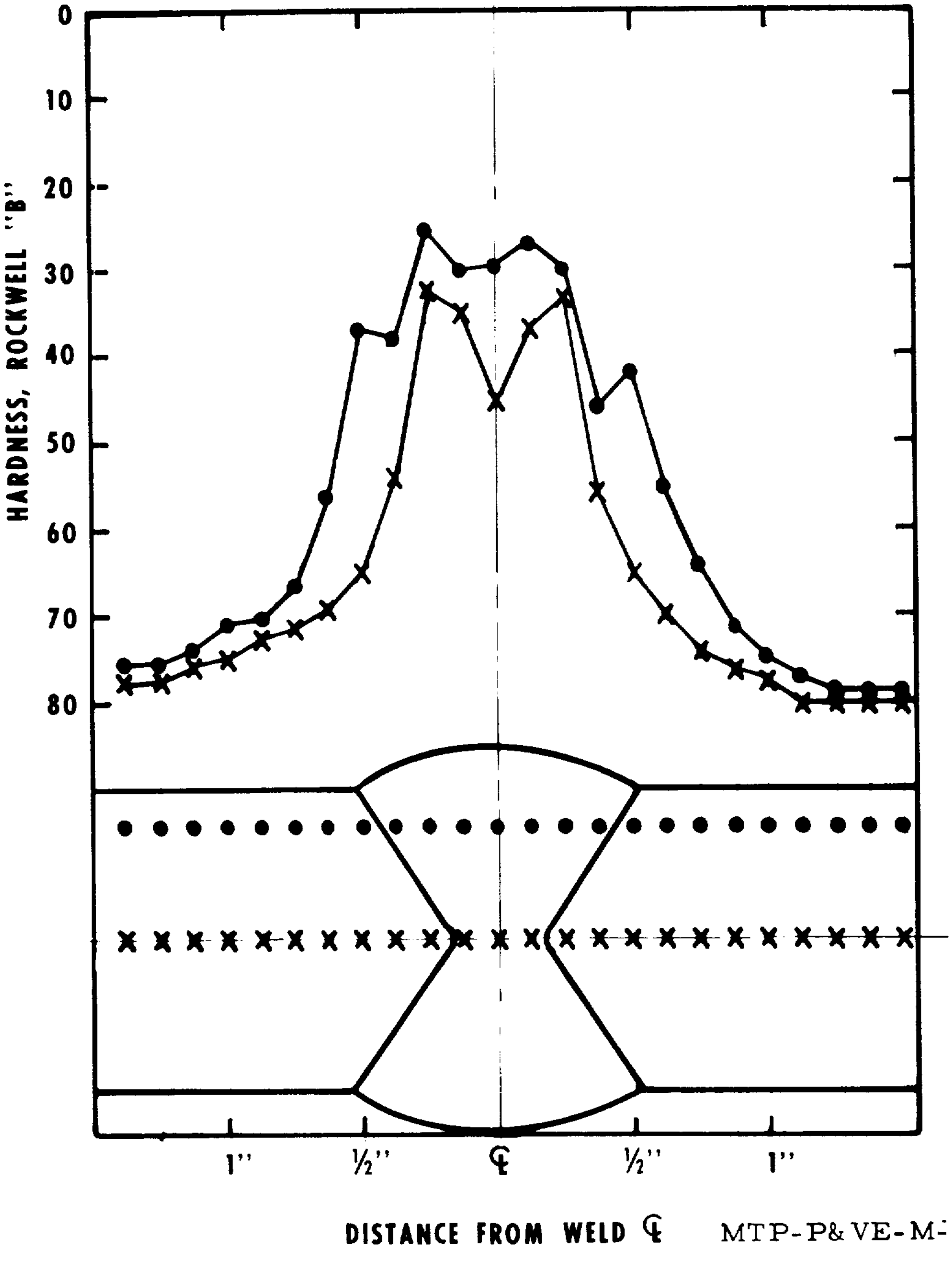

FIGURE 13 HARDNESS TRAVERSE THROUGH WELD AND HEAT AFFECTED ZONE

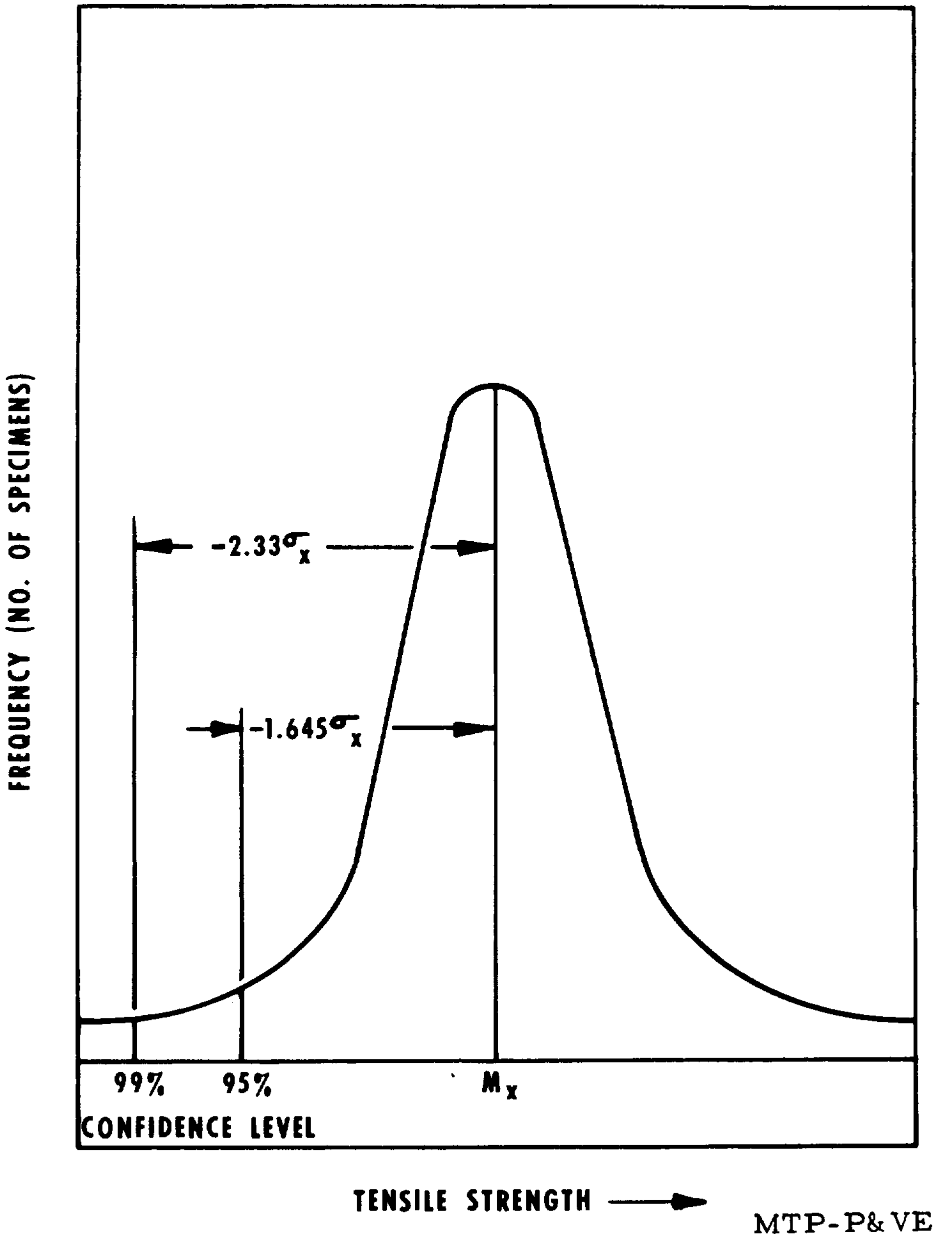

FIGURE 14 NORMAL DISTRIBUTION CURVE - SINGLE TAIL TEST - STUDENT t DISTRIBUTION ANALYSIS

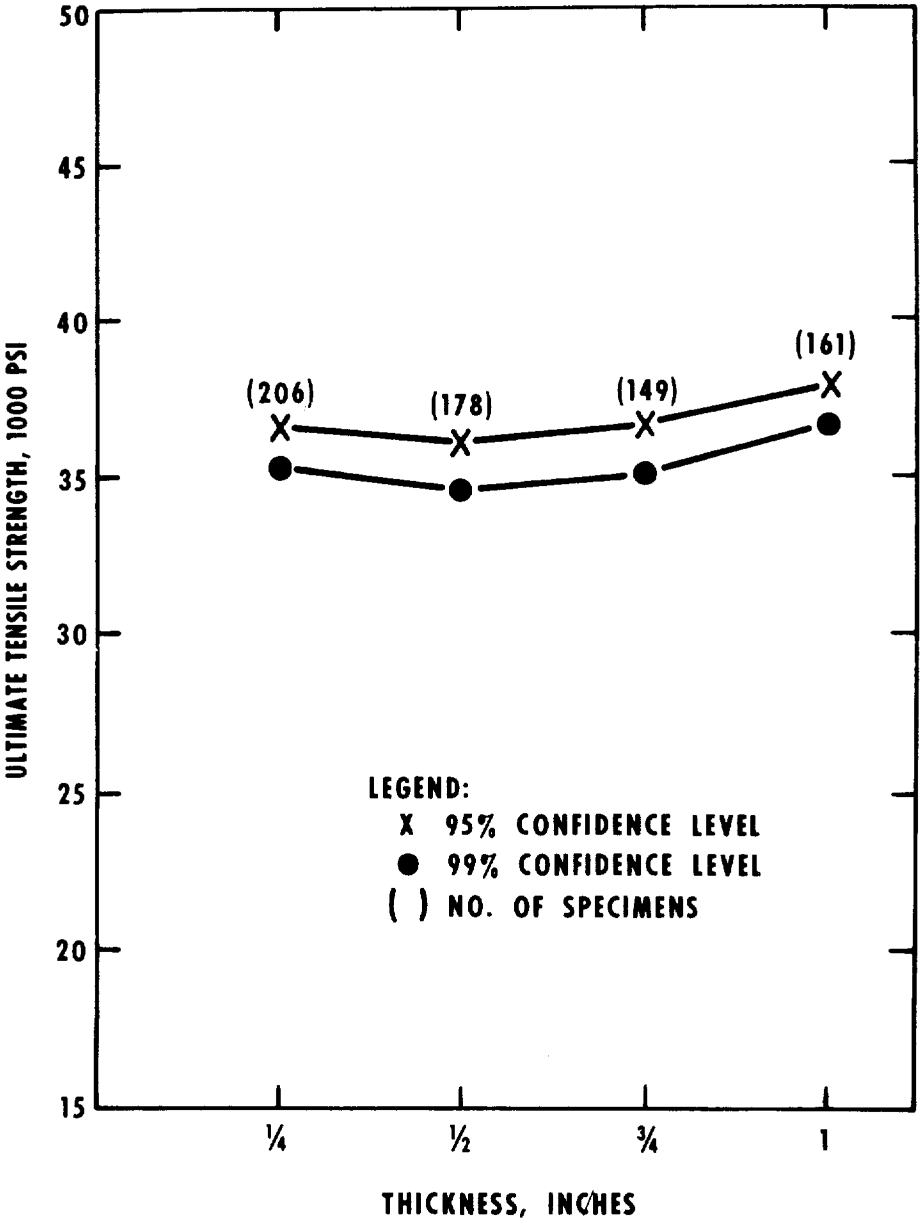

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FIGURE 15 ULTIMATE TENSILE STRENGTH AT 95% AND 99% CONFIDENCE LEVELS

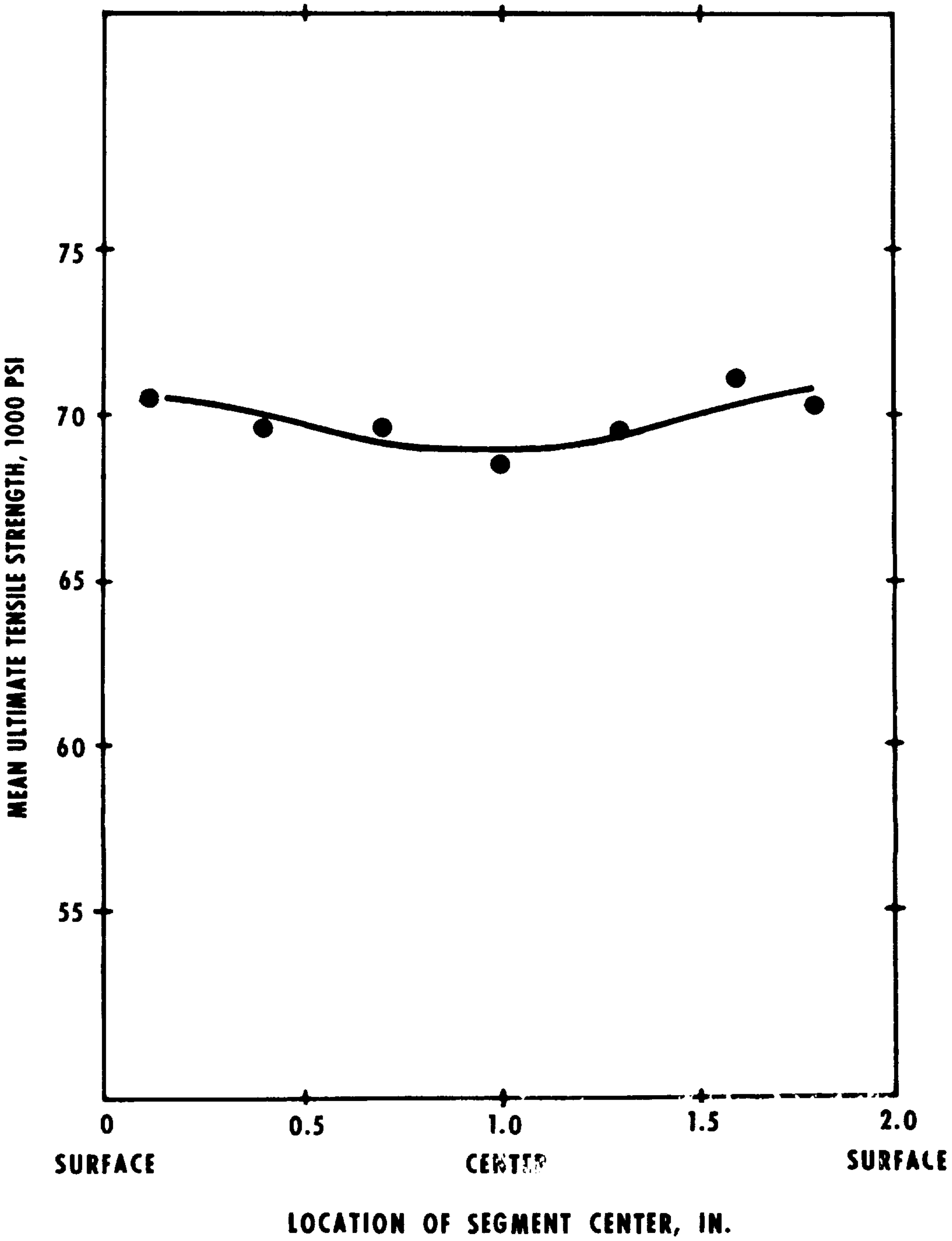

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FIGURE 16 ULTIMATE TENSILE STRENGTH VARIATION THROUGH 2-INCH THICK PLATE

TABLE I

STATISTICAL ANALYSIS OF ULTIMATE STRENGTH OF WELDS IN 2219-T87 ALUMINUM ALLOY (1/4-INCH THRU 1-INCH PLATE)

	MIG Welds	TIG Welds	Combined MIG and TIG Welds
N (Number of test values)	304	390	694
σ_x (standard deviation)	2.23	1.75	1.98
Mx (Mean strength) (Kpsi)	39.6	40.0	39.8
95% Confidence Level (Kpsi)	35.9	37.1	36.5
Percent Conformance	96.4	93.3	95.7
99% Confidence Level (Kpsi)	34.4	35.9	35.2
Percent Conformance	99.0	99.0	99.3

TABLE II

STATISTICAL ANALYSIS OF ULTIMATE STRENGTH OF WELDS IN 2219-T87 ALUMINUM ALLOY (2-INCH PLATE)

N (Number of test values)	47
σ_x (Standard deviation)	2.54
Mx (Mean ultimate strength in Kpsi)	33.8
95% Confidence Level (Kpsi)	29.5
99% Confidence Level (Kpsi)	27.5

TABLE III

COMPARISON OF ULTIMATE STRENGTHS OF WELDED 3/4-INCH THICK SURFACE SEGMENT OF 2-INCH PLATE TO THAT OF EQUAL THICKNESS OF AS-ROLLED MATERIAL

	Ultimate Strength (Kpsi)	
	TIG Welds	MIG Welds
3/4-inch surface of 2-inch plate	42.6	36.3
3/4-inch as-rolled material	42.7	37.8

APPROVAL MTP-P&VE-M-62-16

EVALUATION OF WELDED 2219-T87 ALUMINUM ALLOY

By Richard A. Davis

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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