

## TECHNICAL ORDER

# WELDING HIGH PRESSURE AND CRYOGENIC SYSTEMS

THIS TECHNICAL ORDER IS ISSUED FOR THE PURPOSE OF REINSTATING AND EXTENDING THE EFFECTIVITY PERIOD OF RESCINDED T.O. 00-25-224 DATED 12 OCTOBER 1964.

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## SECTION I

### INTRODUCTION

#### 1-1. GENERAL.

1-2. This technical order is prepared as a directive for personnel engaged in the manufacture, maintenance, and installation of integrated fluid pressure systems that are described in T.O. 00-25-223. Data in this technical order are in agreement with, or have been selected from, codes or accepted standards for welding and testing. In the absence of instructions in a particular technical manual, the information in this manual shall be used or waived by responsible system personnel. Supplementary information is included in appendixes I thru VII pertaining to radiographic, ultrasonic and eddy inspection, mathematical tables, tables of material characteristics, definitions and abbreviations.

#### 1-3. PERFORMANCE QUALIFICATIONS.

1-4. Section II of this technical order shall be followed when it is necessary to qualify welders for work on high pressure or cryogenic systems.

1-5. Section III of this technical order describes qualified welding procedures with certified mechanical properties for various combinations of ferrous and non-ferrous alloys that are fabricated in high pressure and cryogenic systems.

1-6. Section IV of this technical order describes ultrasonic and eddy current testing methods for inspection of weld fabrications of high pressure and cryogenic systems; also qualifications and certification requirements for personnel conducting these non-destructive methods of inspection.

#### 1-7. SUPERVISOR'S RESPONSIBILITIES.

1-8. It is the supervisor's responsibility to:

a. Thoroughly instruct personnel in the safe practices and procedures contained in this technical order.

b. Coordinate with the Ground Safety and Preventative Medicine Officers on any situation that may affect safety of personnel or equipment that is not adequately covered in this technical order.

c. Be constantly alert for hazards and accident producing conditions and take immediate action to remove source of such conditions.

d. Insure that only fully trained and authorized personnel are permitted to perform welding and inspection of welds on high pressure and cryogenic systems.

### NOTE

Section V, Plate Welding Procedures, and Section VI Heat Treatment, of this technical manual will be published at a later date. Until such time as these sections are published, welding methods that have been previously employed shall be used for plate welding.



## SECTION II

### PERFORMANCE QUALIFICATION - MANUAL WELDERS.

#### 2-1. GENERAL.

2-2. This section describes the method for qualification of manual welding operators engaged in welding components for high pressure and cryogenic systems. Excerpts of information from AWS Welding Handbook, Military Specification MIL-T-5021B, Military Standard MIL-STD-248A and ASME Welding Qualification Section IX, dated 1959 have been included to cover the broad range of AF operations encountered in missile, airborne, aerospace ground equipment and facilities (portable and installed property) support systems.

#### 2-3. CLASSIFICATION OF WELDING OPERATORS.

2.4. Welding operators will be classified as follows:

a. Class I welding operators may weld on stress or non-stressed, critical or non-critical, components and accessories in high pressure and cryogenic systems.

b. Class II welding operators are restricted to welding fillet joints for non-stressed, non-critical components and accessories in high pressure and cryogenic systems.

#### 2-5. APPLICABLE DOCUMENTS.

2-6. The following specifications and standards form a part of this section to the extent specified herein:

#### 2-7. SPECIFICATIONS.

a. MIL-I-6868, Magnetic Particle Inspection Process.

b. MIL-I-6865, Inspection Radiographic.

c. MIL-I-6866, Inspection Penetrant.

2-8. STANDARDS. Federal Test Method Metals, Test Method Standard No. 151.

#### 2-9. REQUIREMENTS FOR QUALIFICATION.

#### 2-10. APPLICATION FOR QUALIFICATION.

2-11. APPLICATION FORM. The applicant shall complete in duplicate, Figure 2-1, Application Form. Forms shall be furnished by the AF activity employing the applicant. One copy shall be retained by the applicant's supervisor and the other copy furnished to the responsible Quality Control Inspector.

2-12. DEMONSTRATION OF PROFICIENCY. To achieve qualified status, the operator shall demonstrate his skill or proficiency by welding joints as specified herein for each specific group of material for which qualification is required.

2-13. MATERIALS. The operator shall satisfactorily weld the required joints of representative materials from each group that will be welded in production. For the purpose of this section, the materials are classified as follows:

2-14. Group A. Carbon Steels 40,000 to 75,000 psi minimum tensile strength.

2-15. Group B. Alloy Steels.

B-1 Chromium content not to exceed 3/4%. Total alloy content not to exceed 2%.

B-2. Chromium content between 3/4% and 2%. Total alloy content not to exceed 2-3/4%.

B-3. Total alloy content not to exceed 10%.

2-16. Group C. Stainless Steels.

C-1 Austenitic  
C-2 Martensitic  
C-3 Ferritic

2-17. Group D. Aluminum and Aluminum Alloys

2-18. Group E. Nickel and High Nickel Alloys.

2-19. Group F. Copper and Copper Alloys.

2-20. Group G. Titanium and Titanium Alloys.

2-21. WELDING PROCESS. The welding processes for the purpose of this publication are as follows:

2-22. Oxy-Fuel Gas.

2-23. Metal Arc (coated electrodes).

2-24. Tungsten Inert Gas (TIG).

2-25. Metallic Inert Gas (MIG).

2-26. Carbon Arc.

APPLICATION FOR EXAMINATION OF WELDING OPERATOR

Date \_\_\_\_\_

Name of Applicant \_\_\_\_\_ Date of Birth \_\_\_\_\_

Applicant's Address \_\_\_\_\_ Phone No. \_\_\_\_\_

Applicant's Identification \_\_\_\_\_

Employer \_\_\_\_\_ Location \_\_\_\_\_

Welding Process to be Used \_\_\_\_\_

**APPLICANT'S EXPERIENCE**

Insert time in years in proper space

	AC ARC	DC ARC	Oxy- Fuel Gas	Inert Gas Process (Specify)	Other Remarks
Training (School)					
Plant Production					
Aircraft Production					
Present Employer					

Use back of sheet for additional information

Signature of Applicant \_\_\_\_\_

Figure 2-1. Application for Examination of Welding Operator

**QUALIFIED WELDER'S IDENTIFICATION**

Date \_\_\_\_\_

Welder's Signature

Name \_\_\_\_\_ Identification No. \_\_\_\_\_

Class \_\_\_\_\_ Material or Alloy Group \_\_\_\_\_

Welding Process \_\_\_\_\_

Standard Test \_\_\_\_\_ Special Application \_\_\_\_\_

Welding Procedure Specification \_\_\_\_\_

Signature of Responsible Quality Control Rep \_\_\_\_\_

A 2-1/2 inch by 3-1/2 inch card will be used for this form.

Figure 2-2. Identification Card



**2-27. RECORD OF WELDING VARIABLES.**

2-28. Information concerning welding variables shall be observed and recorded while the respective specimen joints are being welded. Variations outside the limits of the welding procedure specification will be cause for disqualification.

2-29. **PROPERTIES OF JOINTS.** The joints shall be tested and shall exhibit properties meeting all the requirements specified herein.

2-30. **ELIGIBILITY FOR WELDING.** No welding operator shall be permitted to perform any welding operation in connection with any high pressure or cryogenic system until a qualified welder's identification card (Figure 2-2) has been issued.

2-31. **LIMITATIONS.** A welding operator who acquired qualified status by welding an alloy in any of the Groups, Paragraph 2-13, will not be required to take additional examination for alloys in the same group. Operators shall not be permitted to weld joints of materials in any group for which qualification has not been obtained.

2-32. **WELDING PROCEDURE SPECIFICATION.** The welding procedure specification will include the following: welding process, filler and weld metal analysis, preheat treatment, postheat treatment, mechanical properties of test specimen, type of electrode and flux.

**2-33. PREPARATION OF WELDED JOINTS.****2-34. MATERIALS.**

2-35. **Base Metal.** The material to be used for the welded samples of the qualification tests shall conform in nominal composition and mechanical properties with the materials used in production.

2-36. **Filler Metal.** The welding rods or electrodes shall conform to the kinds or types which are regularly used in production work for the material fabricated.

2-37. **Joint Material.** The materials and filler metal for test joints shall be in accordance with paragraphs 2-35 and 2-36, respectively.

2-38. **MATERIAL CONFIGURATION.** The material shall be representative of sizes and gages used in production. Test joints 1, 2, and 3 shall be welded from the greatest outside diameter (range 1-1/4 inch thru 10 inches) and the greatest wall thickness (range 1/4 inch thru 3/4 inch). Test Joints 4 and 5 shall be welded from thickness range 1/8 inch thru 1 inch and 5 inches wide by 6 inches long. The weld, either groove, butt, or fillet, shall be along the 6 inch dimension.

2-39. **SURVEILLANCE OF THE QUALIFICATION.** All test specimens shall be fabricated under control of responsible qualified personnel. All testing shall be done by government-owned or government-accepted laboratory facilities.

**2-40. MATERIAL GROUPS AND WELDING OPERATORS.****2-41. ALL GROUPS.**

2-42. **Class I Operators.** The qualification tests for Class I Operators shall consist of the welding and the inspection of groove or butt welds in Test Joints 1, 2, and 3.

2-43. **Class II Operators.** The qualification tests for Class II Operators shall consist of the welding and the inspection of groove or butt and fillet welds in Test Joints 4 and 5.

**2-44. SPECIMEN JOINTS.**

2-45. **STANDARD JOINTS.** There are two types as shown in Figure 2-3. One type consists of a groove or butt weld joint between sections of pipe or tubing of equal wall thickness. The other type consists of groove, butt, or fillet weld joint between plates of equal thickness. Joints for the above types will be prepared and welded from gage and material combinations used in production. The groove or butt joints may be a "V" or "U" type joint as shown in Figure 2-3, contingent on which is to be used in production.

2-46. **ADDITIONAL SPECIMENS.** Separate qualification tests are required for each combination of materials and welding processes.

2-47. **THERMAL TREATMENT.** Preheating and postheating of the joint area shall be accomplished in accordance with the applicable material welding procedure specification.

**2-48. WELDING POSITIONS.**

2-49. **Joint No 1, Pipe, Overhead Groove or Butt.** The entire weld shall be accomplished with the material at or above the welder's eye level. Two joints shall be prepared, one for a horizontal position and the other for a vertical position with respect to the longitudinal axis of the joint specimen. Figure 2-5 shows correct method for preparing test specimens for this joint.

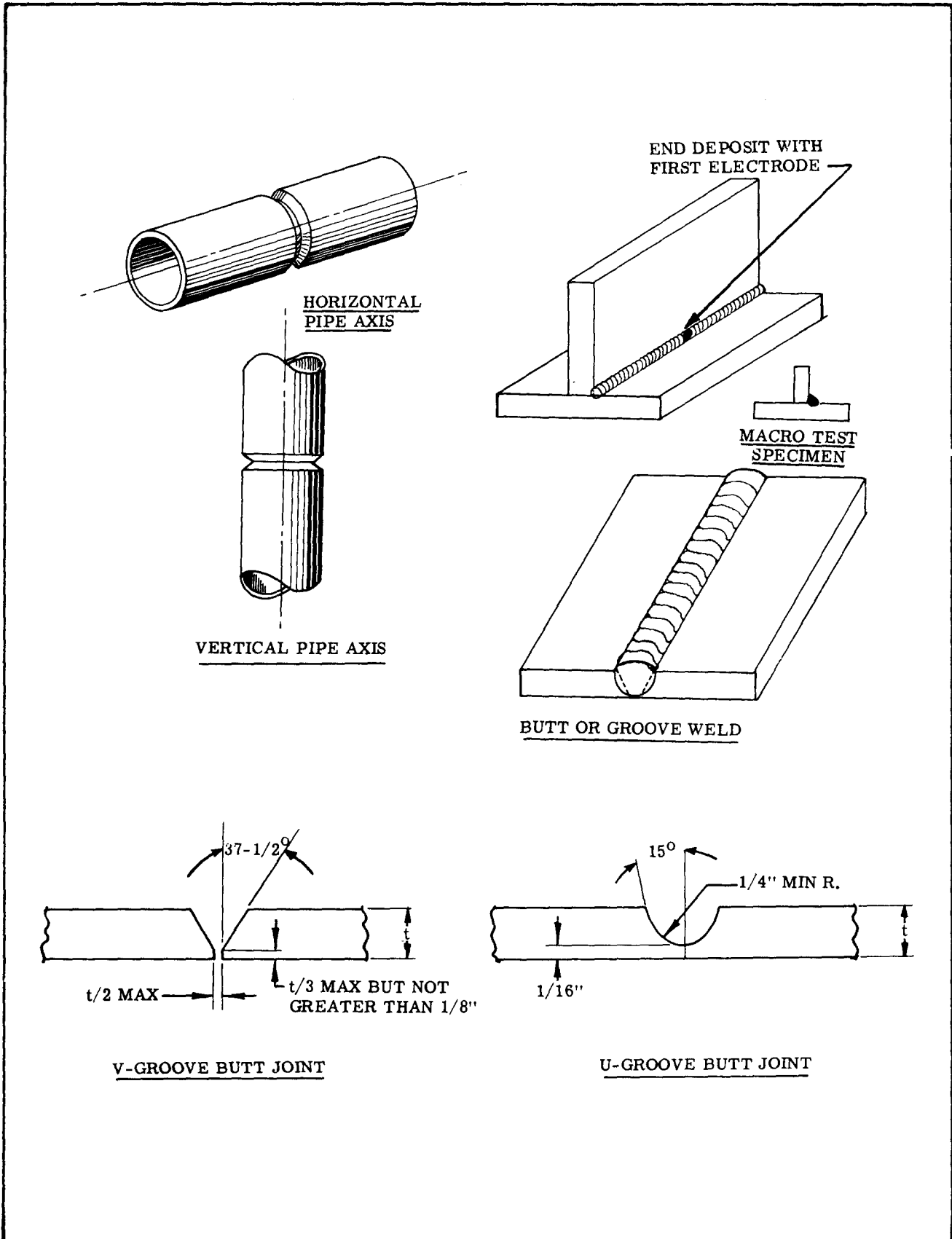


Figure 2-3. Fillet Welded Joint

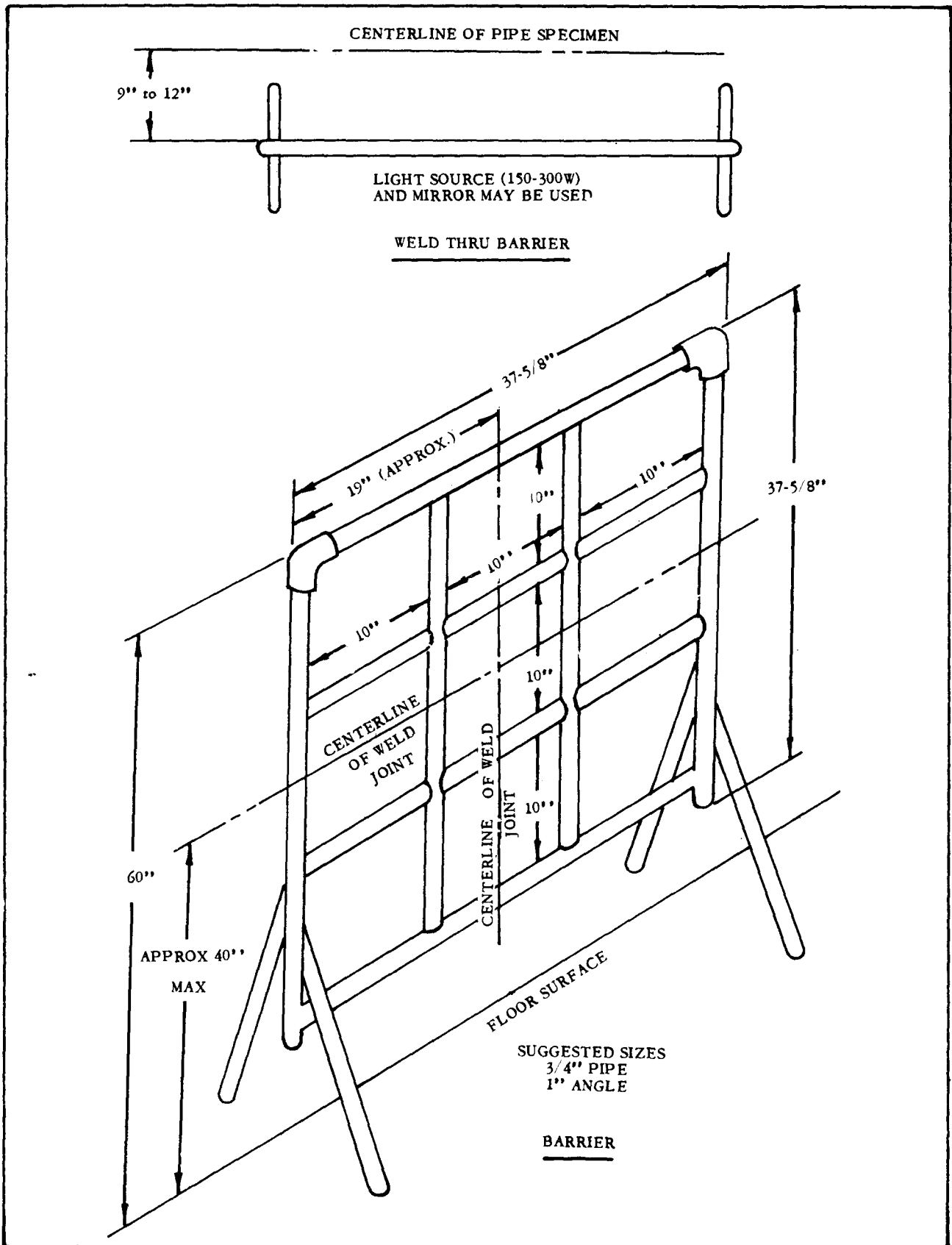


Figure 2-4. Weld Thru Barrier

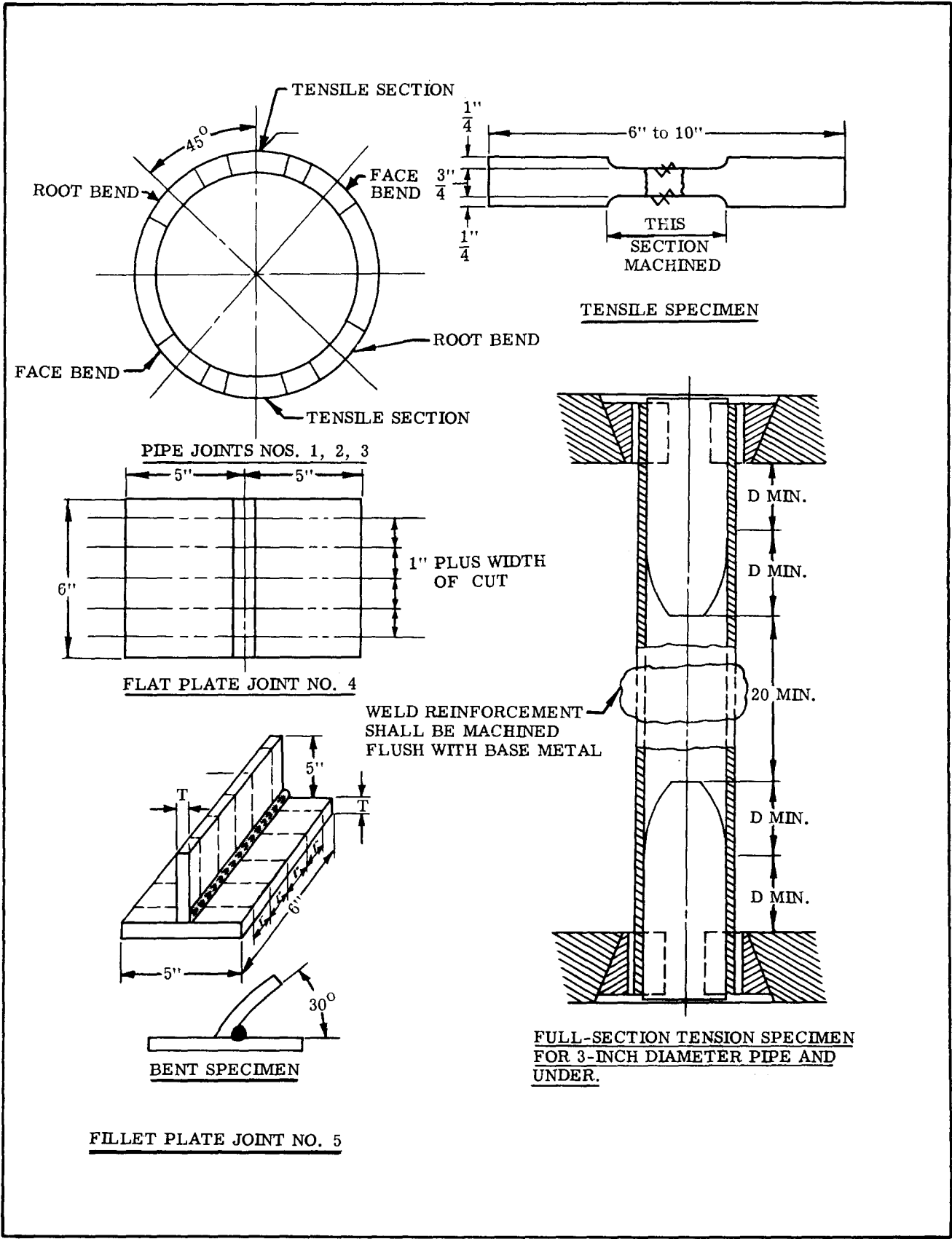


Figure 2-5. Plate Information and Test Specimen Preparation

2-50. Joint No 2, Pipe, Through Barrier, Groove or Butt. The entire weld shall be accomplished with joints located with respect to the barrier as shown in Figure 2-4. The weld shall be made with the welder's arms extended through the barrier from the opposite side of the joint location. Two joints shall be prepared, one for a horizontal position and the other for a vertical position with respect to the longitudinal axis of the joint specimen. The joints shall be secured in a fixed position during welding. Mirror and light source may be used as required. Figure 2-5 shows correct method for preparing test specimens for this joint.

2-51. Joint No. 3, Pipe, Below Ground Level, Groove or Butt. The entire weld shall be accomplished with the joint located, in a simulated trench, at least 6 inches below ground level. Clearance around the weld area of the joint shall be 12 inches  $\pm$  1 inch. Two joints shall be prepared, one for a horizontal position and one for a vertical position with respect to the longitudinal axis of the joint specimen. The joints shall be secured in a fixed position during welding. Mirror and light source may be used as required. Figure 2-5 shows correct method for preparing test specimen for this joint.

2-52. Joint No. 4, Plate, Groove or Butt. Two welds shall be made, one horizontal and the other vertical, at bench level. Also, one weld shall be made in the overhead position. Plate information and test specimen preparation shown in Figure 2-5.

2-53. Joint No. 5, Plate, Fillet. Two welds shall be made, one horizontal and the other vertical, at bench level. Also, one weld shall be made in the overhead position. Plate information and test specimen preparation shown in Figure 2-5.

2-54. SPECIAL APPLICATION. The designs of the specimens for qualification tests may be modified, provided the modified designs are more directly applicable to the intended end product and approval of them is obtained from the responsible Quality Control representative. If the joints in the modified specimen are such as to require less skill in welding than the standard specimens or joints, then the production work of the operator shall be similarly restricted.

#### 2-55. EXAMINATION AND TESTS OF WELDED JOINTS.

##### 2-56. NON-DESTRUCTIVE INSPECTION.

2-57. All welded joints representative of critical or highly stressed sections, classified as such by the design or cognizant engineer for materials welded in production shall be examined by one or more of the following non-destructive test methods as designated by the engineer. Inspection standards for acceptance and rejection of indicated discontinuities in representative welded samples shall be the same as established by the design or cognizant engineer and the Quality Control representative for material welded in production.

2-58. Radiographic Inspection. Welded joints for which radiographic inspection is specified shall be examined by standard radiographic procedure and inspected in accordance with MIL-I-6865. The techniques utilized shall be 2% or better sensitivity to reveal a standard parameter for the appropriate material thickness.

2-59. Magnetic Particle Inspection. Welded joints of ferromagnetic or paramagnetic materials for which Magnetic Particle Inspection is specified shall be inspected by the magnetic particle method as described in MIL-I-6868 for surface and sub-surface discontinuities.

2-60. Penetrant Inspection. Welded joints for which penetrant inspection is specified shall be inspected by the method as described in MIL-I-6866 for surface discontinuities.

2-61. Ultrasonic and/or Eddy Current Inspection. Welded joints for which ultrasonic and/or eddy current inspection is specified shall be conducted in accordance with the specifications stipulated in ANA Bulletin 143 and Section IV of this technical order.

2-62. Visual Inspection. The exposed surfaces of welded joints shall be examined for smoothness of surface, regularity of the weld bead, weld contour surface cracking, craters, lack of fusion and penetration, undercut and overlap. Visible surface cracking shall be cause for rejection.

##### 2-63. METALLOGRAPHIC INSPECTION.

2-64. Preparation of Specimen and Examination of Structure. The fillet welded joint as shown in Figure 2-3, shall be sectioned transverse to the direction of welding and the surface of the section shall be ground and suitably polished for examination visually at a magnification from 3 to 10 diameters for weld characteristics indicated below:

- a. Over-all fusion of weld, root penetration, burn through, and blow holes.
- b. Convexity, concavity, and size of bead or fillet.
- c. Undercutting and overlapping.
- d. Inclusions.
- e. Cracks.
- f. Porosity.

Evaluation of the above characteristics to be shown in Figure 2-6, Inspection Report.

2-65. Requirements. The weld shall be considered satisfactory provided there is no evidence of:

- a. Inclusions (greater than 2% of weld area).
- b. Blowholes.

INSPECTION REPORT

Name of Applicant \_\_\_\_\_ Date \_\_\_\_\_

Welding Process \_\_\_\_\_ Manual or Machine \_\_\_\_\_

Welding Procedure Specification \_\_\_\_\_ Materiel \_\_\_\_\_

Thickness (if pipe, diameter and wall thickness) \_\_\_\_\_

Filler Metal \_\_\_\_\_

Inert Gas Composition \_\_\_\_\_

Trade Name \_\_\_\_\_ Flow Rate \_\_\_\_\_

Is consumable ring and/or gas back-up used? \_\_\_\_\_

Preheat temperature range \_\_\_\_\_

Postheat temperature range \_\_\_\_\_

Single or Multiple Pass \_\_\_\_\_

Position of Groove \_\_\_\_\_

Filler Wire-Diameter \_\_\_\_\_ Flux \_\_\_\_\_

Trade Name \_\_\_\_\_ Forehand or Backhand \_\_\_\_\_

Joint Dimensions \_\_\_\_\_

Amps \_\_\_\_\_ Volts \_\_\_\_\_ Inches per minute \_\_\_\_\_

REDUCED SECTION TENSILE TEST

Joint and Specimen No.	Dimensions		Area	Ultimate Load, Lb	Ultimate Stress PSI	Character of Fracture and Location
	Width	Thickness				

Figure 2-6. Inspection Report (Sheet 1 of 2)

Inspection Report  
(Continued)

Guided Bend Tests

Joint and Specification No.	Result	Type and Figure No.	Result

Fillet Weld Examination

Welds to be Satisfactory or Unsatisfactory		
Item	Defectives	Results
a.	Inclusions (no greater than 2% of weld area)	
b.	Blowholes	
c.	Burn Through (if existing must be satisfactorily repaired)	
d.	Cracks	
e.	Porosity (no greater than 5% of weld area)	
f.	Under Cutting	

Quality Control Inspector \_\_\_\_\_

We certify that the statements in this report are correct and that test welds were prepared, welded and tested in accordance with the requirements of T. O. 00-25-224.

Signed \_\_\_\_\_

Quality Control Inspector

Date \_\_\_\_\_

Welder

Figure 2-6. Inspection Report (Sheet 2 of 2)

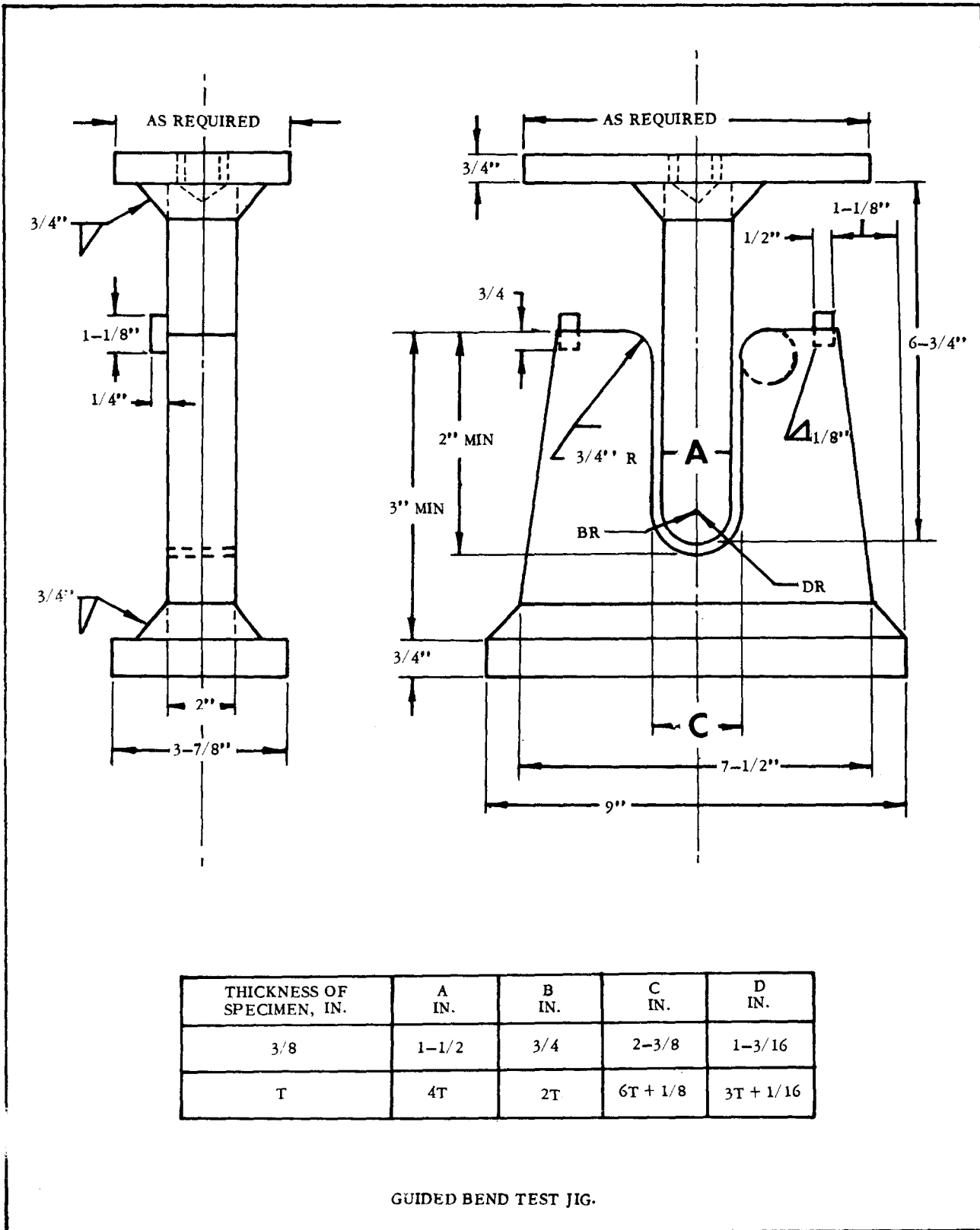


Figure 2-7. Guided Bend Test Jig



- c. Burn through (if existent must be satisfactorily repaired).
- d. Cracks.
- e. Porosity (greater than 5% of weld area).
- f. Undercutting.

**2-66. TENSILE TEST.**

2-67. Preparation of Specimen. Tensile test shall be prepared in accordance with Federal Test Method Standard No. 151, with a 3/4 inch width of test section and with the welded joint transverse to the long dimension, and at the approximate center of the test section, as indicated in the sketch of the tensile specimen of Figure 2-5. Where tensile specimen cannot readily be cut from pipe, entire pipe specimen may be pulled as shown in Figure 2-5. This is only applicable for pipe 3 inches, OD, and smaller. Using this type test eliminated guided-bent test on these small diameter specimens.

2-68. Tensile tests shall be conducted in accordance with the test methods specified in Federal Test Method Standard No. 151, except that ultimate tensile strength only shall be determined. At the discretion of the certifying officer, ductility tests, (elongation & reduction in area), may be utilized.

2-69. Requirement. The weld shall be considered satisfactory when the failure in tension occurs in the Base Metal. Joints failing at the edge of the weld or in the weld metal shall be considered satisfactory only when ultimate tensile strength is equal to or greater than the minimum tensile strength of base metal.

**2-70. GUIDED-BEND TEST.**

2-71. Guided-Bend Specimens. Guided-bend specimens shall be cut according to Figure 2-5.

2-72. Method. The specimen shall be bent in test jigs that are substantially in accordance with Figure 2-7. The side of the specimen toward the gap of the jig determines or classifies the specimen as a root or face bend. The specimen shall be forced into the die by applying a constant load on the plunger until the curvature of the specimen is such that a 1/8 inch diameter wire cannot be inserted between the die and the specimen.

- a. For wall thickness 3/8 inch or less, the specimens shall be bent in the weld 180 degrees over a diameter not to exceed four times the thickness of the welded section. The weld shall be the center of the bend.

- b. For wall thickness above 3/8 inch, the specimens shall be bent so that the root surface becomes the convex surface of the bend specimen for a root bend. The face surface becomes the convex surface of the bend specimen for a face bend.

2-73. Requirements. In order to pass the test, guided-bend specimens shall have no cracks or open defects exceeding 1/8 inch measured in any direction on the convex surface of the specimen after bending, except that cracks occurring on the corners of the specimen during testing shall not be considered, unless there is definite evidence that they result from inclusions, voids, or other internal discontinuity.

**2-74. QUALITY ASSURANCE PROVISIONS.**

2-75. QUALIFICATION AND IDENTIFICATION. If the Application Form (Figure 2-1) and the Inspection Report (Figure 2-6) are satisfactory, the authorized Quality Control personnel shall evaluate an Identification Card conforming to Figure 2-2, and deliver it to the welding operator. The signature of the authorized Quality Control personnel, as applicable on the identification card, shall be considered evidence that the applicant has satisfactorily fulfilled all requirements for the classification noted thereon. This classification shall designate the alloy group and the welding process used as described in paragraphs 2-13 thru 2-26. The welder's identification number will be used in a suitable method of marking welds made by the operator.

2-76. This identification card shall be valid only on work done for the military installation in whose name it was issued and shall become void 12 months from the date of the last entry on the reverse side. In the absence of the authorized Quality Control representative signatures and dates shown on the reverse side of the card shall be made by the cognizant engineer or the foreman of the welder.

2-77. PROCEDURE SELECTION. To insure that a welder qualifies on cryogenic systems, care shall be taken to follow closely the procedures set forth in Section III of this technical manual. The procedures will instruct personnel on the choosing of correct electrodes for the base material to be welded, to insure the weld metal having resistance to low temperature embrittlement that closely approaches that of the base metal.

### NOTE

No welds shall be made on any material that is not covered by Section III of this technical manual. In event it is necessary to weld on material other than those covered by this technical manual, the prime agency for this technical manual, MOAMA/MONENB, shall be contacted for coordination on the procedures and performance qualifications.

**2-78. MAINTENANCE OF STATUS.** The qualified status of an operator shall be maintained by a continuous production record of satisfactory workmanship for production items where welding complexity is comparable to test specimens in paragraph 2-66. Evidence of satisfactory workmanship shall be entered on the reverse side of the identification card within 6 months after qualification. The elapsed time between reviews of the operator's workmanship shall not exceed 6 months.

**2-79. REQUALIFICATION.** Re-examination will be required when any change affects the welding process or when the operator has discontinued welding in production for a period of 6 months on the process for which operator is qualified.

### NOTE

When there is reason to question the proficiency of the welder or quality of workmanship by responsible qualified personnel, re-examination will be required of the operator.

**2-80. INTENDED USE.** This technical manual is intended for use in ascertaining that prospective welding operators for high pressure or cryogenic systems possess a satisfactory level of proficiency

#### **2-81. DEFINITIONS.**

a. **High Pressure.** High pressure as used in this technical manual is defined as pressures of 500 PSI and above.

b. **Continuous Production Record.** Continuous production record requires a minimum of 16 hours during each 4-week period after initial qualification.

c. **Cryogenics.** The science which involves very low temperatures, usually regarded as below  $-150^{\circ}\text{F}$ .

d. **Critical or Highly Stressed Areas.** This condition exists where a safety factor of 4 or less has been designed in the cross sectional weld area of production materials. Joints representative of these cross sectional weld areas shall be examined as described in Section IV.

**SECTION III****PROCEDURE QUALIFICATION - MATERIALS WELDED.****3-1. GENERAL.**

3-2. This section provides information necessary for a welder to become proficient in the special techniques required for welding on high pressure systems.

3-3. This section is divided into parts as follows:

a. GENERAL - giving general background information.

b. GENERAL WELDING PROCEDURES - giving procedures applying to all welding methods.

c. SPECIFIC WELDING PROCEDURES - provides special procedures for the various methods of welding.

d. QUICK REFERENCE CHART.

e. SPECIFICATION LIST AND DETAILED WELDING PROCEDURES are intended to give quick cross reference to find methods and details for the welding of various metals and metal combinations.

f. CERTIFIED WELDING PROCEDURES and CERTIFICATION OF TEST DATA give the technical information necessary to make and prove a satisfactory weld.

3-4. To find the necessary data the following procedure may be followed:

a. The materials to be welded, being known, reference to the Quick Reference Chart (Figure 3-20) will indicate the specifications that may be used.

b. The exact specification that meets requirements is selected by referring to the List of Specifications (page 3-50).

c. Refer to Detailed Welding Procedures (Figure 3-21) for filler metal, paragraphs in the text in which procedures are described, and figure numbers for correct qualification procedures and certification data.

d. Reference to the certified qualification procedure figure gives the technical information (heat, amps, volts, welding speed, etc.) necessary to make the weld. The certification of data sheet will indicate what the strength of the finished weld should be if procedures were in accordance with the instructions in this Technical Order.

3-5. Values given in the certified procedures and test data are those used in developing the procedures and are not meant to be restrictive. They are given as a guide for the welder.

3-6. SAFETY. Welders are exposed to many types of injuries. Light rays, splashing metal, poisonous fumes, gases, and electrical shock can all cause painful or serious injury. The proximity of flammable substances or hazardous locations provide additional danger. Because of the danger to personnel and property damage, it is essential that safe welding practices be observed at all times.

3-7. PERSONAL SAFETY EQUIPMENT. All welding personnel, before starting a welding operation, shall protect themselves with approved helmets, goggles, shields, aprons, gloves, gauntlets and other protective clothing as required. Eye protection lens in helmets, etc., shall be of the shades specified in paragraphs 3-145, 3-209, and 3-244.

3-8. VENTILATION. When natural ventilation is insufficient to prevent accumulation of dangerous gasses and fumes, forced ventilation shall be used. Local exhaust ventilation shall be used in confined spaces and if fumes cannot be kept to safe limits, appropriate breathing devices shall be worn. When welding in a missile silo or other confined space at least 15 changes of air an hour shall be provided. Ventilation for all conditions shall conform to or exceed American Welding Society standards.

3-9. FIRE HAZARDS. All necessary safety precautions shall be taken before welding is begun near flammable or explosive materials. Suitable fire extinguishers shall be provided, all flammable material shall be removed, or if removal is impossible, cover with a fire resistant shield. Wooden floors or other combustible material shall be protected. Upon completion of the welding operation a careful inspection shall be made for possible sources of potential fire. Before welding is started the possibility of fire or explosion shall be eliminated by removal or ventilation in areas where flammable or explosive gases are present. When a fire hazard cannot be eliminated, the decision to weld shall be made by the Fire Marshal and a fully equipped fire guard shall stand by until welding is completed.

3-10. Compressed gases. Various types of gases are used by the Air Force in welding operations. The following precautions will cover minimum precautions in handling compressed gases.

3-11. Gas cylinders shall be stored in approved spaces only and secured by chains or other suitable means.

3-12. Cylinders permitted inside of buildings shall be stored a minimum of 20 feet from highly combustible materials and in locations where they are not liable to excessive rising temperature, physical damage, or tampering by unauthorized personnel.

3-13. Unless separated by a minimum of 20 feet there shall be a fire resistant partition between the oxygen cylinders and fuel cylinders.

3-14. Cylinders stored in the open shall be protected from the weather.

3-15. Suitable equipment shall be used when moving cylinders. Slings and electromagnets shall not be used.

3-16. Trucks of special design shall be used for transporting cylinders.

3-17. Oxygen equipment shall be kept grease free.

3-18. Cylinders shall not be dropped or handled roughly.

3-19. Oxygen and compressed gas cylinders shall never be used without pressure regulators.

3-20. Oxygen shall not be used for ventilation.

3-21. Cylinders in use shall be secured in an upright position.

For details of the safe handling of compressed gases refer to T.O. 42B5-1-2.

3-22. Welding on tanks or other containers. Before welding on these items check to see if flammable or explosive materials are or have been, contained therein. If so, they shall be purged or inerted prior to welding. Sealed containers shall be vented before and during the welding operation. Flammable liquid tanks shall be drained, flushed, and steamed, filled with water if possible and adequately vented before and during welding.

3-23. Trichloroethelene degreasers shall not be located in the welding area. (Minimum distance 300 feet). Fumes from the degreaser will form phosgene gas when in contact with the welding torch. Any variance from the above shall be coordinated with the medical officer.

3-24. Plated Materials. When welding plated materials, cadmium, galvanizing, etc., adequate local ventilation, i.e., portable flexible exhaust duct with a minimum of 4000 linear feet base velocity, shall be provided to remove toxic or poisonous gases. Respirators shall be worn if there is any doubt of ventilation adequacy. Ventilation shall equal or exceed the requirements of the American Welding Society.

3-25. All safety precautions of AFM 32-3 and AFP 161-2-2 shall be followed in welding operations.

### 3-26. PROCEDURES.

3-27. Every welding operation involves numerous factors or variables which influence the properties of the resulting weld. For this reason, a welding procedure specification is used to define a given welding procedure and limit the variables involved in that procedure.

3-28. All metals cannot be welded without the use of special materials and supplementary operations in that some metals, more than others, are susceptible to alteration caused by heat generated during the welding process. The application of heat produces a variety of structural, thermal, and mechanical effects on the metal being welded, and on any metal which may be added in making the weld. Technique of application, base metal, and filler metal characteristics are prerequisites for producing a weld that is metallurgically equal to the service for which it is intended.

3-29. The quality of welded joints will be determined by the specific welding procedure used in production of the final weld. Predictable results as to the mechanical properties and soundness of such joints can be obtained only by adherence to a welding procedure that has been thoroughly investigated. It cannot be expected that good results will be obtained, even when performed by careful and painstaking personnel, if poor materials or fundamentally improper methods are used.

3-30. In the welding of a given metal, the properties and characteristics of the weld metal and of the base metal in the immediate vicinity of the weld may be changed by using a different welding process or procedure. The mechanical properties of the weld metal, such as tensile strength, yield strength, and ductility will be determined by the particular process and procedure that is used.

3-31. Metals used for welded applications consist of low carbon steel (0.30 percent or less), high carbon steels, alloy steels, and non-ferrous metals.

3-32. Practical experience has proved that all of these metals cannot be welded with the same degree of ease. The degree of precaution necessary to obtain good quality welded joints in high carbon steel, alloy steels, non-ferrous metals and dissimilar metal combinations, varies widely. Most of these metals are considerably more difficult to weld than mild steel.

3-33. When new metals are introduced for a given service, the control of welding processes and procedures demands more supervision to assure the desired engineering results, upon which the successful application of the process depends.

3-34. If a welding procedure specification is to be effective, it must have competent supervision to insure that all welds made in accordance with that specification will possess substantially the same properties.

3-35. High quality weld metal can be obtained in welded joints in nearly all types of steel and non-ferrous metals, provided the proper welding process and procedure are employed.

3-36. Sample welds have been made and tested to qualify each welding procedure incorporated in this manual. A certified report of the physical test results, with certified reports of the mechanical properties and chemical analyses of the base metal and weld metal used for each welding test, are included in this section.

3-37. Included in these developed procedures are all steps necessary to produce a weldment which will exhibit the optimum mechanical properties in the base metal and weld metal for both similar and dissimilar metal combinations.

3-38. Temperatures specified by paragraphs in this Technical Order may be determined by any of the commercially available methods.

3-39. When combined, the following three controls will insure the production of consistent welds of known properties:

- a. The proper use of the qualified welding procedures presented in this manual.
- b. Qualification of the operator to determine his ability to deposit sound welds, as required by Section II of this manual.
- c. Supervision and inspection during welding, to determine that all details of the prescribed welding procedure specification are performed on production welding.

### 3-40. WELDING CONTROL SPECIFICATIONS.

3-41. To obtain satisfactory results during welding, it is necessary to examine the factors affecting the deposition of sound weld metal.

3-42. The following factors will govern quality.

- a. Cutting and Edge Preparation.
- b. Cleaning.
- c. Fitting Up and Tack Welding.
- d. General Requirements.
- e. Starting the Arc.
- f. Breaking the Arc.
- g. Arc Blow.
- h. Angle of Electrode
- i. Welding Current.
- j. Travel Speed.
- k. Electrodes and Filler Metals.
- l. Oxy -Acetylene Welding.
- m. Preheating.
- n. Interpass Temperature Control.
- o. Postheat Treatment.
- p. Distortion Control.
- q. Peening.
- r. Conformance to Welding Procedure Specifications.
- s. Engineers Quality Requirements.

### 3-43. CUTTING AND EDGE PREPARATION.

3-44. Edges or surfaces of parts to be joined by welding may be prepared by machining, shearing, flame-cutting, or other suitable means. Regardless of which method is used, the resulting joint must meet the required geometry, and must provide a sound, bright, metal surface.

3-45. It is desirable to control the geometry of the joint to minimize any notch condition that might lead to concentration of stress. Sharp corners, or sudden changes in size or contour are to be avoided.

### 3-46. CLEANING.

3-47. Cleanliness along the joint and on the sides of welding edges is of the utmost importance to obtain a satisfactory weld. Therefore, the welding edges should be free of oxides, grease, oil, scale, paint, dirt, or other foreign matter. Paints that contain low-melting metals, such as zinc and lead can cause cracking if allowed to contaminate the weld deposit; foreign material in the joint can cause low-quality welds. Dirt and other foreign material on the welding edges cause porosity, slag inclusions, blowholes, incomplete fusion, and oxidation.

3-48. All metal that is to be fused during welding must be absolutely clean. This is a basic requirement to obtain sound weld metal in a weld deposit. Cleanliness is imperative to edges that have been prepared for welding, to electrodes, and to surrounding equipment such as welding benches, jigs, hold-down devices, etc. Cleanliness also is a requisite to flux coating remaining on weld metal or base metal upon which subsequent weld metal is to be deposited.

### 3-49. FITTING UP AND TACK WELDING.

3-50. Joint alignment is maintained by use of jigs and fixtures or by adequate tack welds. The external support shall be adequate to hold the joint in place and to ensure that no partially completed joint is subjected to excessive external tensile or bending stresses. The external support shall not be so rigid as to prevent normal weld shrinkage and thereby bring about such high stresses that cracking of the weld would result.

3-51. Tack welds, when used for alignment and holding purposes, shall be properly placed and of sufficient size to support the joint throughout the welding operation. In addition, the pipe or structure shall be supported and braced to prevent transverse movement.

3-52. The spacing between parts to be joined shall be carefully considered. The root opening between lands or welding edges for a given thickness of material must permit the gap to be bridged without difficulty, yet shall be large enough to allow full penetration of the weld deposit. Specifications for spacing of the joint in production welding shall be adhered to rigidly.

3-53. Welding edges of pipe-to-pipe, pipe-to-fittings, and pipe-to-valve joints shall be aligned as accurately as is practicable within commercial tolerances on pipe diameters. Alignment shall provide the most favorable conditions for the deposition of the root weld deposit, and shall be preserved during welding. In cases where ends of unequal internal diameter are abutted, the internal misalignment must not exceed a maximum of 1/16-inch at any point for the full length of the joint.

In event the internal misalignment exceeds 1/16-inch the pipe with the smaller internal diameter shall be trimmed by machining the inside, so that the adjoining internal diameters will result in approximately the same thickness. In no case shall trimming of the inside diameter result in a wall thickness less than the minimum required for service conditions.

### 3-54. GENERAL REQUIREMENTS.

3-55. In the fabrication of certain metal combinations, cracking has been observed in the deposited metal. Cracking during welding usually occurs as the deposited metal solidifies, or is cooling to interpass temperature. This phenomenon is associated with the chemical and metallurgical characteristics of the deposited metal, and in general, can be adequately controlled through proper welding procedures and techniques.

3-56. In practically all cases, a short arc length is desirable. A long arc favors oxidation of elements, and can affect the mechanical properties of the weld metal.

3-57. Weaving the electrode during welding should be carefully controlled. A slight transverse oscillation, as opposed to a string bead technique, is often helpful in avoiding entrapped slag along the welding groove. However, if the weaving motion is excessive, the molten pool of metal may not be adequately protected by the shielding medium at all times. When welding with covered electrodes, the width of the weave shall be not over three times the electrode diameter. At no time shall the welding arc be directed into the solidified slag. The maximum weave permissible in inert-gas metal arc welding is determined by the size and shape of the gas cup on the torch, and the composition of the weld metal.

3-58. Hot-cracking is promoted by increasing the width of the bead, and by decreasing the throat thickness. For example: a wide fillet bead with a concave face will have a greater tendency to produce longitudinal hot-cracking in the center of the bead than a narrow, or string bead with a flat or convex face.

3-59. Unnecessarily heavy weld reinforcement on the face of a butt joint, or sharp change in section thickness between weld and base metals shall be avoided because of the problems that arise with stress concentration at the toe of the weld. Since the strength of the weld often exceeds that of the base metal, reinforcement can be held to a minimum. Overlap or undercut shall not be present.

## WARNING

Make sure helmet, shield or goggles are in place before striking the arc.

## 3-60. STARTING THE ARC.

3-61. The three basic methods of initiating an inert-gas, nonconsumable electrode welding arc are:

- a. Scratch start
- b. Retract start
- c. High-frequency start.

3-62. The scratch start is used when performing manual welding. The workpiece is scratched lightly with the electrode; as soon as the arc is struck, the electrode is withdrawn approximately 1/8-inch above the workpiece to avoid contaminating the electrode in the molten puddle. The arc may also be struck on a heavy piece of copper attached to the workpiece, and then carried to the starting point of the weld.

3-63. Retract starting is used on mechanized DC welding applications. The electrode is fed down until contact is made with the work, and is then retracted to establish the arc.

3-64. High-frequency starting can be used with either DC or AC power supplies on either manual or mechanized application. When AC power is used, the convenience of high-frequency starting is a natural by-product of the high frequency employed to stabilize the power supply. This method has the advantages of eliminating the need to touch the workpiece with the electrode, and excluding the resultant risk of contaminating the electrode.

3-65. The high-frequency starter can be controlled from a foot switch or a switch mounted on the handle of the holder. This allows the starter to be cut off until the operator is ready to start welding. Using this switch, the high frequency can be shut off upon completion of a weld. Arc craters can be properly filled by using the high frequency to start and stop the arc intermittently while filling the crater.

3-66. The foot-operated heat control is also highly advantageous in avoiding craters. The foot-operated control permits a gradual build-up, and reduction of the welding current. Incorporation of these controls has proved to be sound engineering practice, in that greater safety and more satisfactory welds result.

3-67. Striking the arc on the base metal is to be avoided in areas where subsequent welding will not remove the effects of the arc crater.

## 3-68. BREAKING THE ARC.

3-69. In metal arc welding, when breaking the welding arc, a crater will form if an inadequate amount of molten metal is available to fill the arc plasma cavity. Arc craters may be weld defects because the last metal to solidify freezes under a high degree of constraint and contains an accumulation of weld metal segregates. These conditions can produce hot-cracking and subsequent failures. Various procedures are commonly employed to break the arc. One method requires that the arc be shortened and the electrode moved quickly to the side and out of the crater. This method is used in manual welding when electrodes are changed and the weld is to be continued from the crater.

3-70. When the arc is re-established in the crater, it should be struck at the forward end of the crater, moved backward over the crater, and then forward again to continue the weld. The crater is filled when this procedure is used, and porosity and trapping of slag are avoided.

3-71. Arc craters should be carefully filled at the end of a bead, or pass of weld metal, by holding the electrode stationary a sufficient time to fill the crater, and then the electrode should be gradually and slowly withdrawn. This method is used in manual, semiautomatic, and automatic welding.

## 3-72. ARC BLOW.

3-73. Arc blow is a phenomenon encountered principally when welding with direct current. Under some conditions it may be encountered with an alternating current, but to a lesser degree. Direct current flowing through the electrode and base material sets up magnetic fields around the electrode, which tend to deflect the arc from its intended path. Unless the arc blow is unusually severe, corrective steps will counteract the conditions causing the arc blow. One or more of the following corrective steps may be necessary to control arc blow:

- a. Use back-stepping procedure on long welds.
- b. Place ground connections as far as possible from joints to be welded.
- c. If back blow is encountered, place the ground connection at the start of the weld.
- d. If forward blow is encountered, place the ground connection at the end of the weld.

e. Wrap the ground or lead cable around the workpiece and pass ground current through it in such a direction that a magnetic field will be set up to neutralize the blow.

f. Point the electrode so that the arc force counteracts the arc blow.

3-74. Severe arc blow shall be controlled to the extent that weld metal deposited under these conditions will not contain excessive defects, or be subject to subsequent failure.

#### 3-75. ANGLE OF ELECTRODE.

3-76. The angular position of the electrode to the work may determine to a marked degree the quality of the weld. Upon this position may depend the ease with which the filler metal is deposited, the freedom from undercutting and slag inclusions, and the uniformity of fusion and weld contour. Recommendations of electrode manufacturers shall be followed in all cases.

3-77. The lead angle of the electrode is the angle between the joint and the electrode taken in a longitudinal plane; the work angle is the angle between the electrode and the work taken in a plane normal to the joint plane. Increasing the lead angle in the direction of welding ordinarily builds up a bead. An excessively large work angle may result in undercutting.

3-78. When using certain electrodes, such as the low-hydrogen types, the control of electrode angle, as well as arc length, is of major importance in maintaining weld quality.

#### 3-79. WELDING CURRENT.

3-80. Recommended ranges of welding current are provided by electrode manufacturers. Generally, the current shall be held as low as possible within the recommended range, but shall produce proper fusion and penetration. High welding current is to be used with caution, since hot-cracking may occur as a result of alloy loss, excessive dilution, or the deposit shape.

3-81. The welding current, electrode size, mean voltage, welding technique, and manner of depositing the weld metal shall be such that there will be no undercutting on the side walls of the welding groove or adjoining base metal. Each bead or layer of deposited weld metal shall blend smoothly and gradually with the base metal.

#### 3-82. TRAVEL SPEED.

3-83. Travel speed is an important factor in arc welding because of its influence on weld penetration. An increase in welding current alone is not an efficient method of producing penetration. A more effective technique involves an increase in travel speed with a commensurate increase in current so that the electrode and arc dwell on the base metal ahead of the molten weld metal.

#### 3-84. ELECTRODES AND FILLER METALS.

3-85. Coated shielded-arc type electrodes utilize the benefits of chemical coatings. It is by use of this type of coating that the arc characteristics, and the physical and chemical properties of the deposited metal can be controlled. These coatings not only produce a protecting shield of non-oxidizing or reducing atmospheres around the arc, but also control fluidity of the metal, penetration, shape of the beads, physical properties of the deposit, and may control the composition of the deposit by addition of various metals and alloys.

3-86. The covered metallic electrode is a precision tool. The composition of the core wire is closely controlled, and the covering is designed and specified to accomplish predetermined results. Special attention must be given to the uniformity and concentricity of the thickness of the covering. Care should be exercised in its use not to break the covering by careless handling, or bending the electrode to obtain questionable advantages. If an electrode is bent, it will be necessary to discard a large portion of that electrode.

3-87. All containers (bundles and boxes) of electrodes or filler metals shall be legibly marked on the outside, showing:

- a. The classification and specification number.
- b. The manufacturer's name and trade designation.

3-88. Provisions shall be made to keep electrodes and filler metals clean and dry. It is good practice to retain them in the original shipping containers until such time as they are to be used. Most covered electrodes will pick up a sufficient amount of moisture to be a source of trouble during use if the covering is exposed to the atmosphere. This may be remedied by storing the electrodes in a heated cabinet.



3-89. An identification system shall be established and maintained which will insure that only the correct type of electrode or rods will be available for a specific weld. Under no conditions shall an electrode or rod be used if the identification has been destroyed, or is not plainly visible. A welder shall not carry more than one type of electrode or rod when performing a given welding operation.

3-90. A complete inventory of welding electrodes and filler metals shall be maintained at all times.

3-91. The welding procedure specifications will specify the type or classification of electrode or filler metal to be used for each weld. It is the responsibility of the Welding Supervisor to assure that each welder uses the correct type of filler rod.

### 3-92. OXY-ACETYLENE WELDING.

#### WARNING

Devices or attachments facilitating or permitting mixture of air or oxygen with combustible gases prior to consumption except at the burner or in a standard torch or blowpipe shall not be allowed unless approved for the purpose.

#### WARNING

Use of liquid acetylene is prohibited.

#### WARNING

Tests of any piping system or apparatus for leaks shall be made with soapy water. Use grease free soap. Never use flames to detect leaks.

#### WARNING

Acetylene gas shall not be brought into contact with unalloyed copper except in a blow-pipe or torch.

#### WARNING

Never support welding on compressed gas cylinders or containers.

#### WARNING

Never attempt to transfer any gas from one cylinder to another or to mix gasses in a cylinder.

#### WARNING

All applicable safety precautions included in this manual shall be followed for oxy-acetylene welding operations.

3-93. Oxy-acetylene welding shall be performed with the torch tip pointed forward in the direction in which the weld progresses; this method is called the forehand technique. In general, the forehand technique is recommended because it provides better control of the weld puddle, resulting in a smoother weld.

3-94. Acetylene welding torches shall be lighted with a friction lighter. The instructions of the equipment manufacturer must be observed when adjusting operating pressures at the regulators and torch valves before gases, issuing from the torch tip, are ignited.

3-95. It is characteristic of the oxy-acetylene flame that a degree of control can be maintained over the carbon content of the deposited weld metal, and over the portion of the base metal, which is heated to its melting temperature.

3-96. When the oxy-acetylene torch is used with an oxidizing flame, a rapid reaction results between the oxygen and the carbon of the metal. Some of the carbon is eliminated in the form of carbon monoxide. The steel itself and other constituents are also oxidized. When the torch is used with an excess-acetylene flame, carbon is introduced into the weld puddle.

3-97. The following three types of flame adjustment are used:

3-98. Neutral Flame. The neutral flame is obtained most easily by adjustment from an excess-acetylene flame, which is recognized by the feather extension of the inner cone. The feather will disappear as the flow of oxygen is increased. Just at the point of feather disappearance, the neutral flame is obtained.

3-99. Carburizing Flame. The practical method of determining the amount of excess acetylene in a flame, when a reducing or carburizing flame is desired, is to compare the length of the feather with the length of the inner cone, measuring both from the torch tip. A "two-time" excess-acetylene flame is composed of an acetylene feather which is double the length of the inner cone. The welder can produce the desired acetylene feather by increasing the acetylene flow or by decreasing the oxygen flow.

3-100. Oxidizing Flame. The oxidizing flame adjustment is given as the amount by which the length of the inner cone is reduced. Starting with the neutral flame, the welder can increase the oxygen or decrease the acetylene, until the length of the inner cone is decreased to the desired amount.

3-101. The proper type of flame, with the correct welding technique, can be used as a shielding medium which will reduce the oxidizing and nitrogenizing effect of the atmosphere on the molten metal. Such a flame also has the effect of stabilizing the molten weld metal, and preventing the burning out of carbon, manganese, and other alloying elements.

3-102. The proper type of flame for any application is determined by the type of base and filler metal, the thickness of the base metal, and the welding position. For most metals, a neutral flame is used. An exception is the welding of aluminum, where oxy-hydrogen is the preferred method. When oxy-acetylene is used a slightly carburizing flame with a 1/8" to 1/4" feather should be used. For welding stainless steel a carburizing flame with a 1/16" feather should be used.

3-103. The type of flame used, and the welding technique employed in welding various materials, will determine the quality of the weld deposit. Specific requirements of the welding procedure specifications (paragraphs 3-242 through 3-271) shall be adhered to carefully.

3-104. In event a particular welding operation is not covered by a given welding procedure specification, the recommendations of the manufacturer of the base metal and filler metal must be observed.

#### 3-105. PREHEATING.

3-106. Preheating involves raising the temperature of the base metal or a section of the base metal above the ambient temperature before welding. This may vary from as low as room temperature (70°F) when welding low carbon steels, to as high as (60°F) when welding highly hardenable steels. In many welding operations, the temperature to which the base metal is heated must be strictly controlled.

3-107. The need for preheating increases as the following factors are changed:

- a. The larger the mass being welded.
- b. The lower the temperature of the pieces being welded.
- c. The lower the atmospheric temperature.
- d. The smaller the diameter of the weld rod.

- e. The greater the welding speed.
- f. The higher the carbon content of the steel.
- g. The higher the manganese content.
- h. The greater the alloy content in air-hardening steels.
- i. The more the air-hardening capacity of the steel.
- j. The greater the difference in mass between the two pieces being joined.
- k. The more complicated the shape of section of the part.

3-108. Preheating is a very effective means of reducing weld-metal and base metal cracking. It also improves weldability generally, but has two major beneficial effects. It retards the cooling rates in the weld metal and heat-affected base metal; and it usually lowers the magnitude of shrinkage stresses.

3-109. Weld metal shrinkage is reduced by preheating. Utilization of this often-overlooked fact can mean the difference between an acceptable or unacceptable weldment. A preheat of 200°F to 600°F is a primary factor in the prevention of cracking in low-alloy steels.

3-110. Residual stresses may be produced by overheating and underheating. Pre-heating, therefore, should be carefully controlled. The method of heating should be such as to give uniform heating around the circumference of the pipe or structure. If the entire weldment is not heated, the band of metal heated to the specified temperature should be equal to at least three times the width of the weld, and the temperature should diminish gradually outward from the weld.

3-111. The method of applying heat should be such that the temperature around the joint is uniform. Torch heating may produce high temperature gradients through the wall and around the circumference of a pipe, unless care is taken to apply heat uniformly at the proper rate around the joint.

3-112. The effects of high-temperature gradients are both metallurgical and mechanical in nature. Metallurgical effects involve micro-structural changes. Mechanical effects involve thermal contraction of the weldment which may produce localized distortion, or high residual stress.

3-113. Recommended preheating temperatures for each type of material and welding operation are presented in paragraph 3-183. These preheat temperatures and the method of applying heat must be carefully controlled.

## 3-114. INTERPASS TEMPERATURE CONTROL.

3-115. Interpass temperature is the temperature of the weld metal just prior to depositing the second and subsequent passes. In multiple-pass welding, the interpass temperature is the preheat temperature for the ensuing bead. The time interval between beads controls this temperature.

3-116. In most cases, control of interpass temperature is as important as control of preheating temperature. As an example, a test plate preheated to a certain temperature will meet minimum requirements. If the same preheat temperature is used on a large structure, and the time between depositing the successive passes is greater than that for the test plate, the interpass temperature may fall below the required minimum preheat temperature, and a welded joint in the structure may fail to meet minimum requirements.

3-117. To insure that the maximum temperature is not exceeded, and the minimum temperature is maintained in production welding, the recommended interpass temperatures for each type of material and welding operation are presented in paragraph 3-186. Under no conditions should the interpass temperature be allowed to exceed the specified maximum or fall below the specified minimum.

## 3-118. POSTHEAT TREATMENT.

3-119. In general, postheating becomes more necessary as the dimension and thickness and/or hardenability of the materials increase. With the less hardenable materials, postheating is generally required only above a certain minimum dimension and thickness, while the more hardenable materials may require postheat treatment, regardless of physical dimension.

3-120. The heating rate of a weldment to the postheat temperature is established by the requirement of limiting the maximum temperature differential to 150°C through the thickness of the material. The maximum rate of cooling from the postheat temperature is also determined by the same factor.

3-121. Postheat treatment may be necessary for a number of reasons, and may require nothing more than controlled cooling to room temperature after welding, or may require subsequent heat treatment to obtain the desired properties in the weld and base metal. Stress relieving by postheat treatment has been specified herein for the physical integrity of the weld. Where stainless steels are welded that are susceptible to stress corrosion and carbide precipitation deficiencies, the Design or Project Engineer shall designate the corrective post heat treatment procedures.

3-122. Where postheat treatment is required for a particular welding operation, the postheat temperature, and details of the postheat procedure, will be specified in the applicable Certified Qualification Procedure.

## 3-123. DISTORTION CONTROL.

-124. Generally speaking, there are two basic means of controlling distortion:

a. Distribute and balance the forces and stresses produced by weld shrinkage by special welding techniques and sequences.

b. Forcibly restrain movement of the parts being joined by use of suitable jigs and fixtures.

3-125. Both of these methods attempt to increase the plastic flow of the weld metal during the cooling period. This means that both methods are subject to the same possibility of cracking the weld metal if either method is used to an extreme.

3-126. The shrinkage force can be reduced by limiting to a minimum the amount of weld metal deposited to meet service requirements. The strength of a joint is determined by its design. No added strength of a joint is accomplished by the addition of filler metal in excess of the amount specified by the design; however, the effective shrinkage force is increased.

3-127. Reduction of heat input is an effective means of minimizing shrinkage. Minimal shrinkage can also be accomplished by using lower amperages, using small diameter electrodes (or a combination of both), and torch manipulation in oxy-acetylene welding. Shrinkage can also be minimized by use of correct welding techniques. Intermittent welding, back-step welding, or use of the wandering sequence prevents local build-up of heat; this results in a reduction in shrinkage. The shrinkage distortion can be reduced by placing welds as near as possible to the neutral axis. The closer to the neutral axis, the less is the leverage exerted to pull sections out of alignment.

3-128. An effective way to control and reduce distortion during welding is to restrain the parts forcibly. This method can eliminate distortion completely in certain operations, if the restraint is sufficiently great. Greater restraint, however, may increase the magnitude of stresses during welding. This applies particularly to the transverse stress; hence the greater tendency to cracking.

3-129. In all welding operations where distortion is a factor to be avoided, the direction of welding should be away from the point of restraint and toward the point of maximum freedom.

**3-130. PEENING.**

3-131. Peening has been employed with success for stress-relieving purposes. When properly applied, it causes plastic flow of the metal, and subsequently relieves the restraint that originally set up the residual stresses. Effective peening, however, requires considerable judgement. Excessive peening may result in cold-working and strain-hardening of the material, and may set up new residual stresses.

3-132. Manual peening is rarely satisfactory, since it cannot be controlled properly. A pneumatic chisel with a blunt, rounded edge is recommended.

3-133. Hot and cold peening of weld metal has resulted in unexpected difficulties in a number of instances. Peening in many cases has been utilized as an easily applied remedy for some particular condition, such as eliminating cracking, with little or no forethought given to the eventual consequences of the operation. Peening has been used to prevent the appearance of hot cracks in the surface of weld beads. This is a deluding and dangerous practice, because cracking has often developed internally in the bead, and the peening only serves to prevent its propagation to the surface.

3-134. When peening is necessary to stress-relieve weld metal or to control distortion of heavy sections, it must be properly applied and carefully supervised.

**3-135. CONFORMANCE TO WELDING PROCEDURE SPECIFICATIONS.**

3-136. The appearance of a weld does not necessarily indicate its quality. If defects exist in a weld, they may or may not be apparent to visual inspection. A visual examination of the underside of a weld will determine whether complete penetration has been obtained, or whether excessive globules of metal, burn-through, etc., are present. Oversized and undersized welds can be observed readily. Undercut or overlap at the sides of the welds can usually be detected through visual inspection. Other defects, such as incomplete fusion, porosity, and cracking may or may not be externally apparent. Excessive grain growth, or the presence of hard spots, definitely cannot be determined visually. Therefore, the specific requirements of the developed welding procedure specifications shall be followed carefully to assure that all details of the welding procedure specifications are incorporated in the production weld.

3-137. Welds made in accordance with an adequate joint welding procedure specification, when performed by competent welding operators, will meet minimum requirements. Thus, when the results of a given welding procedure are tested and found satisfactory for a

given application, all other welds made in accordance with the same joint welding procedure should be of acceptable quality.

3-138. The adoption of welding procedure specifications is a form of standardization. In cases where a number of welding operators might select different electrode sizes, and employ different welding techniques for the same joint, the adoption of a welding procedure specification results in the use of a single standard welding procedure by all operators.

**3-139. ENGINEERS QUALITY REQUIREMENTS.**

3-140. Welds having one or more of the following defects shall be repaired, or cut out and rewelded:

- a. Weld is not reasonably uniform in appearance.
- b. Undercutting adjacent to completed weld.
- c. Evidence of undercutting removed by grind and/or polishing.
- d. Obvious gas pockets or slag inclusions are present.
- e. Cold laps in deposited weld metal.
- f. Evidence of peening (where not authorized).
- g. Weld profiles are not within the accepted tolerances.
- h. Overlap of weld metal on base metal.
- i. Less than 100 percent penetration for the entire length of the weld.
- j. Underhang in excess of allowable dimensions on inside of pipe.
- k. Unfilled craters resulting from improper breaking of the arc.
- l. Cracks of any description in weld or base metal.
- m. Evidence of damage to weld or base metal through oxidation.
- n. Depressions in welds below the base metal surface on either side of the welded joint.
- o. Tungsten inclusions.
- p. One or more welds do not meet the required tests.

3-141. All welding shall be subject to inspections during and after completion of the welding operation. Defects so discovered shall be carefully noted as to exact location, and shall be corrected by removal of all defective metal by any suitable mechanical process, and rewelded. All welding performed to correct a defective weld deposit shall be done in accordance with the applicable welding procedure specification.

3-142. The approval of the Project Engineer or Welding Supervisor shall be required before any defective welds are repaired. Welds, which in the opinion of the Project Engineer or Welding Supervisor cannot be successfully repaired, must be cut out and rewelded.

3-143. It shall be the responsibility of the Welding Supervisor to ascertain that each welder uses the correct type of filler metal for the material being welded.

#### 3-144. GENERAL WELDING PROCEDURE SPECIFICATIONS.

### WARNING

All safety precautions, paragraphs 3-6 through 3-9, 3-22 and 3-24 shall be observed when performing arc welding operations.

3-145. Eye protection lenses shall be as follows:

a. For resistance welding, clear lenses and filter lenses up to and including shade No. 2 to protect the eyes from nearby cutting and welding operations.

b. For arc welding filter lenses shade No. 6 when welding with 30 amperes or less, shade No. 8 when cutting or welding with 30 to 75 amperes, shade No. 10 when using 75 to 200 amperes, shade No. 12 when using 200 to 400 amperes and shade No. 14 when welding current is greater than 400 amperes.

3-146. Fire resistant curtains or screens shall be used during arc welding operations to protect personnel from eye injuries caused by intense arc flashes and to reduce the fire hazard.

3-147. Circuits on arc welding equipment will be checked only when the circuits are dead. Rotary and polarity switches will not be operated while the equipment is under electrical load.

3-148. Arc welding equipment shall be safety inspected periodically and any necessary repairs made by a qualified electrician. Power cables and electrode holders, in particular, shall be given careful inspection for defects that could cause shock.

#### 3-149. PREPARATION AND WELDING OF PIPE, VALVES, AND FITTINGS FOR ALL WELDING PROCESSES.

#### 3-150. REQUIREMENTS.

3-151. The procedures outlined in paragraphs 3-152 through 3-207 are the general requirements for preparation and welding of pipe, valves, and fittings for all welding processes. Specific requirements for manual inert-gas shielded tungsten arc and oxy-acetylene welding are discussed in paragraphs 3-208 through 3-241, and 3-242 through 3-271, respectively.

#### 3-152. PREPARATION OF BASE METAL.

### WARNING

To prevent injury, impact type goggles or face shield shall be worn by personnel when engaged in grinding or buffing operations.

3-153. The edges or surfaces of parts to be joined by welding shall be prepared by machining, grinding, cutting with abrasive disc, or other approved mechanical methods (carbon steels may be flame-cut). Prior to welding, all edges or surfaces shall be thoroughly cleaned of all oxides, oil, grease, paint, dirt, or other foreign matter. Surfaces to be welded shall be free of all residue.

3-154. Only alloy steel or hardened carbon steel tools shall be used in cutting or fabricating stainless steels, copper-nickel, nickel alloys, and/or nonferrous metals. Grinding wheels to be used for grinding shall be of alumina oxide or equal. Wire brushes used for cleaning shall be stainless steel. Grinding wheels and wire brushes shall not have been previously used on materials other than the material being fabricated.

#### 3-155. BEVELS FOR PIPE, VALVES, AND FITTINGS.

3-156. Welding edges of carbon steels, stainless steels, nickel alloys, and ferrous metals with a wall thickness of 3/4-inch or less, shall be beveled at a 37-1/2 (+2-1/2 )-degree angle, leaving a 1/16 (+1/32)-inch root face land at the bottom of the welding edge (see figures 3-1 and 3-2). Pipe saddle joints shall be beveled in the same manner as butt welds.

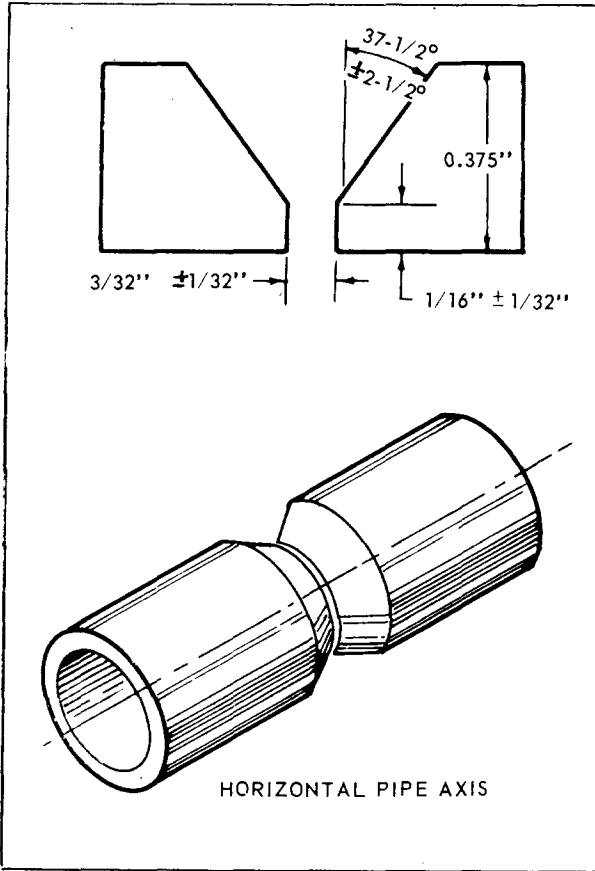


Figure 3-1. Weldment with Root Opening - Horizontal Attitude

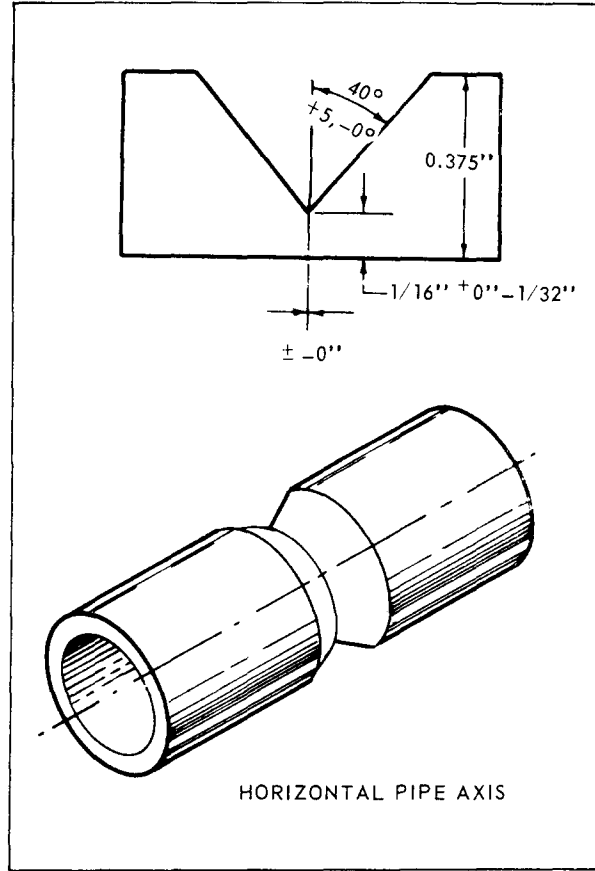


Figure 3-3. Weldment with No Root Opening - Horizontal Attitude

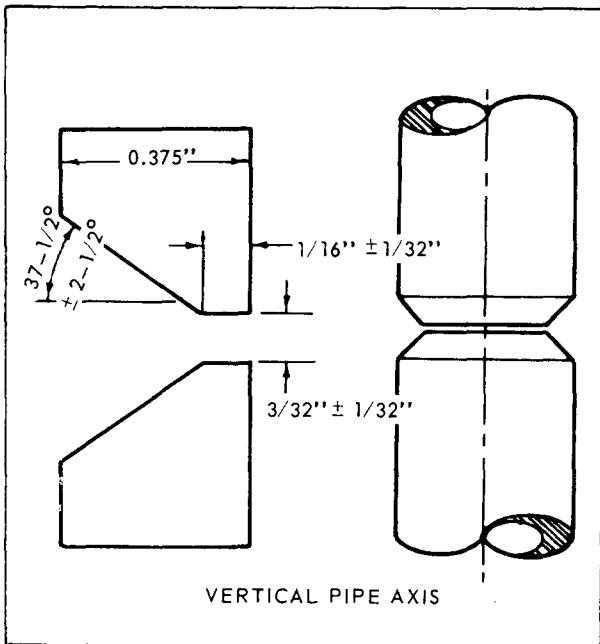


Figure 3-2. Weldment with Root Opening - Vertical Attitude

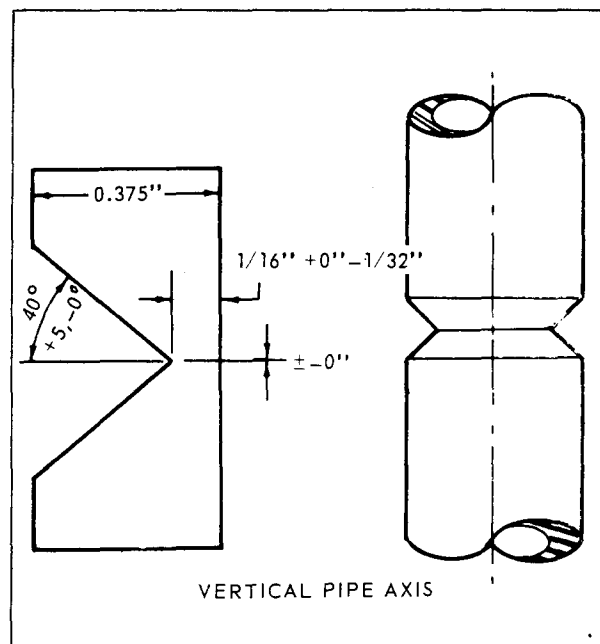


Figure 3-4. Weldment with No Root Opening - Vertical Attitude

3-157. Welding edges of aluminum and non-ferrous metals, with a wall thickness of 3/4-inch or less shall be beveled at a 40 (+5, -0)-degree angle, leaving a 1/16 ( $\pm 0-1/32$ )-inch root face land at the bottom of the welding edge (see figures 3-3 and 3-4). Pipe saddle joints shall be beveled in the same manner as butt welds.

3-158. In event operating personnel have a doubt as to the nature of the joint or its preparation, the Project Engineer shall be consulted before proceeding with any further preparation or welding of the joint in question.

#### 3-159. FITTING UP AND TACK WELDING.

3-160. Pipe-to-Pipe, Pipe-to-Valves, and Pipe-to-Fittings.

3-161. Joints which require a root opening shall have a separation between lands or welding edges of 3/32 ( $\pm 1/32$ )-inch for the full length of the joint (see figures 3-1 and 3-2.)

3-162. Joints which require no root opening shall have the lands or welding edges butted together so that the lands are touching and the beveled edges form a groove. There shall be no clearance between lands (see figures 3-3 and 3-4).

3-163. Joints which require a consumable insert shall have the lands or welding edges butted tight to the insert. Separation between lands and insert shall not exceed 1/32-inch at any point for the full length of the joint (see figures 3-5 and 3-6).

3-164. The ends of pipe, fittings, and valves shall be aligned accurately. In no case shall the welding edges be offset from each other in excess of 1/16 inch, or 1/5 of the wall thickness of the lighter material at the joint, whichever is less.

3-165. The thickness of lands or welding edges may be varied to insure complete penetration of the root weld deposit.

3-166. Slip-on flanges shall have a space from face of flange to end of pipe for fillet weld equal to thickness of pipe wall.

3-167. Welding neck flanges shall be fitted up in the same manner as butt welds.

3-168. All parts to be joined by welding shall be securely held in correct position by jigs, clamps, clips, or other suitable devices, or by tack welds. Holding devices shall be adequate to maintain alignment of all parts throughout the entire welding operation. Tack welds shall be of the same quality and made by the same procedure as the completed weld or shall be removed prior to welding at the point where the tack weld is located.

3-169. Temporary clips, lugs, saddles, etc., welded to base metals while fitting up parts, shall be of like material, using the specified welding rods or electrodes; under no conditions shall dissimilar metals be used for this purpose without specific approval of the Project Engineer.

#### 3-170. OTHER WELD JOINTS.

3-171. Weld joints not specified shall be made as directed by the Project Engineer.

#### 3-172. REBUILDING JOINTS.

3-173. Welding edges of joints shall not be rebuilt or repaired prior to welding without specific approval of the Project Engineer.

#### 3-174. FIXED POSITION WELDING.

3-175. The orientation of weld joints with respect to horizontal and vertical planes of reference shall be in accordance with Figure 2-3. Welding shall be accomplished without pipe rotation, so that weld metal is deposited from the overhead, vertical, flat, and horizontal fixed positions.

3-176. Welding shall be started at the bottom of the joint and progress upward to the top of the joint; under no conditions shall welding be performed in the reverse order. The horizontal reference plane is taken to lie always below the weld under consideration. Inclination of axis is measured from the horizontal reference plane toward the vertical.

#### 3-177. WELDING MACHINES.

### WARNING

To prevent injury to personnel, frames of all welding machines shall be thoroughly grounded to prevent electrical shock. All leads to the electrode, and ground connections on the work, shall be of sufficient size to carry the electrical current with a minimum of resistance. Secure electrical connections shall be maintained between the machine and the work.

**CAUTION**

3-178. Welding machines shall be standard equipment AC or DC, designed for continuous operation, and capable of providing a constant supply of electrical current sufficient in amount and of proper voltage to maintain the welding arc in a stabilized condition throughout the welding operation. Welding machines shall not be operated over 70% of the rated capacity as indicated on the manufacturer's nameplate attached to the welding machine.

To prevent damage to the material being welded, postheating of weld deposits or base metal to straighten or align a weldment is not permissible.

**3-179. ELECTRICAL CHARACTERISTICS.**

**3-187. SEQUENCE.**

3-180. Welding current shall conform with respect to both voltage and amperage (and polarity, when direct current is used) as recommended by the manufacturer(s) of the base metal and filler metal being used.

3-188. The welding sequence shall be such as to avoid needless distortion; a back-step or wandering sequence shall be used where necessary, or when so directed by the Project Engineer.

3-181. Welding carbon steels, stainless steels, nickel alloys, and ferrous metals with the manual metal arc process using covered welding electrodes, shall be performed using direct current and reverse polarity (electrode positive).

3-189. When welding joints of unequal thickness, the arc shall be directed in such manner that both pieces being welded are heated to identical temperatures.

**3-182. PREHEATING.**

**3-190. Multi-Layer Welding.**

3-183. When the temperature of the base metal is less than 70°F, the base metal shall be preheated to a minimum of 70°F (or at least warm to the touch) for a distance of three inches on each side of the joint before welding is started. Under no conditions shall the temperature of the base metal and/or weld deposits be allowed to fall below 70°F while fabrication is in progress or before the welding is completed. This shall be considered a minimum requirement; the preheat treatment for a specific type of material or a given welding procedure, shall be as noted in the Certified Qualification Procedure for each respective welding procedure where required.

3-191. When weld joints require multi-layer welding, starting and stopping points of successive passes shall be staggered and each layer shall be not more than 1/8-inch thick; the several layers shall be made successively, completing each layer before starting the next.

3-184. Welding shall not be performed when surfaces are wet from rain, or snow; when rain or snow is falling on the surfaces to be welded; or during periods of excessive air currents unless the operator and the work are properly protected by suitable shelter.

3-192. All fillet welds shall have a leg dimension not less than 1.80 times the wall thickness of the lighter of the two sections being welded, but in no case shall the throat dimension of the weld be less than the wall thickness of the lighter of the two sections being welded. Unless otherwise specified the faces of fillet welds shall be at equal angles to sections they join.

**3-185. INTERPASS TEMPERATURES.**

**3-193. CONTROLS.**

3-186. Interpass temperatures for stainless steels, copper-nickel, nickel-copper, and nickel alloys shall not exceed 300°F before the next successive pass of welding is started. Interpass temperatures for other ferrous and non-ferrous metals shall not exceed the maximum preheat temperatures as noted in the Certified Qualification Procedure for each respective welding procedure. Each pass of weld deposit shall be allowed to cool to the maximum preheat temperature before additional weld metal is added. Weld deposits shall be allowed to cool by natural means; use of air, water, or other liquids for cooling is not permitted.

**3-194. Weld Metal Deposit.**

3-195. Welding current, electrode size, mean voltage, and manner of depositing the weld metal shall be such that there will be no undercutting on the side-walls of the welding groove or adjoining base metal. Each bead or layer of deposited weld metal shall be uniform, and shall blend smoothly and gradually with the base metal. Cracks or defects that appear in any bead or layer of weld deposit shall be removed before depositing the next successive bead or layer of weld metal in that location.



3-196. Root weld deposits shall have full penetration for the full length of the joint, and shall be started midway between tacks; subsequent passes shall be started 1/4 to 1/2-inch on the preceding pass. After every interruption of the arc, except at completion of a pass, the arc shall be restarted ahead of the previous deposit and then moved back to fill the crater. This technique will insure complete filling of the crater; complete fusion between the new and old deposits and the base metal at the point of junction; and complete resultant continuity of weld. Unfilled arc craters in weld deposits are not permitted, and will be rejected.

3-197. Before welding over previously deposited weld metal, all traces of oxides, slag and foreign material shall be removed from the weld deposit, and the weld deposit and adjoining base metal shall be wire-brushed until thoroughly clean at all points. This shall apply not only to successive layers, but also to successive beads and to the overlapping area wherever a junction is made when starting a new bead or layer. All materials must be bright and clean throughout the welding operation.

3-198. Butt Welds.

3-199. Butt welds shall have one pass for each 1/8-inch of pipe wall thickness, with a minimum of two passes.

3-200. Butt welds and saddle welds shall be flush with inside of pipe. In cases where grinding is not possible, the following even underhang dimensions are allowed:

<u>Pipe Size</u>	<u>Maximum Protrusion</u>
Up to 2 inch	1/32-inch
2-1/2-inch and over	1/16-inch

3-201. Butt welds shall have a finished bead width approximately 1/16-inch on each side of the bevel. Under no conditions are wide welds to be used to cover poor fit-up.

3-202. Reinforcements.

3-203. Reinforcement of butt welds shall be not less than 1/16-inch, nor more than 3/32-inch above the surface of the base material. Reinforcement shall be built up uniformly from the surface of the base material to a maximum at the center of the weld, and shall blend smoothly and gradually with the base material. Finished weld contours shall be uniform and free from depressions below the surface of the base material.

3-204. Post-Weld Inspection.

3-205. Appearance of completed welds shall be reasonably smooth and uniform, and free from surface defects. All slag, weld spatter, metal ejected from the arc, and foreign matter shall be removed from surfaces of weld deposits and adjoining base materials. Completed fabrication shall have bright, clean, surfaces.

3-206. Peening. Peening of weld metal and/or base metal is not permitted except when so specified.

3-207. Radiographic Examination. Welds which require radiographic examination shall have the outside and inside weld ripples or surface irregularities removed (where possible) by any suitable mechanical process. Removal of irregularities shall be such that the resulting radiographic contrast due to any remaining irregularities, cannot mask or be confused with that of any objectionable defect. Also, the weld surfaces shall merge smoothly into the base metal surfaces; the finished surface of the reinforcement shall have a uniform crown not to exceed that of the specified dimension.

### 3-208. INERT GAS SHIELDED TUNGSTEN ARC WELDING PROCESS.

**WARNING**

All safety precautions paragraphs 3-6 through 3-23 and 3-146 thru 3-148 shall be observed when performing Inert-Gas Shielded Tungsten arc welding.

3-209. Eye protection lenses for this type of welding shall be:

- a. Shade No. 6 when welding with up to 30 amperes.
- b. Shade No. 8 when welding with 30 to 75 amperes.
- c. Shade No. 10 for welding with 75 to 200 amperes.
- d. Shade No. 12 when welding with 200 to 400 amperes.
- e. Shade No. 14 when the welding operation requires over 400 amperes.

3-210. REQUIREMENTS.

3-211. WELDING TORCHES.

3-212. Inert-gas shielded tungsten arc welding torches shall be the standard water-cooled type. The size and capacity of torches shall be as recommended by the equipment manufacturer for the electrical current and size of tungsten electrode being used.

3-213. TUNGSTEN ELECTRODES.

3-214. Tungsten electrodes shall conform to American Society for Testing Materials (ASTM) designation B297-55T, Classification EWTH-2, approximately two percent thoriated.

3-215. Preparation of Electrode.

3-216. Tungsten electrodes used for the inert-gas shielded tungsten arc process shall have a long taper and rounded point to lessen the possibility of the point breaking off, burning, or fusing, and causing tungsten inclusions in the welds.

3-217. INERT GAS.

3-218. Inert gas for shielding and for purging shall be argon gas welding grade, or helium XX charcoal purified, or a mixture of the two. Argon and helium shall be tested for moisture with a dew-point tester before being used. When moisture is present, the gas shall not be used for welding or purging. No oxygen content is permissible.

3-219. CONSUMABLE INSERTS.

3-220. The material of the insert shall be compatible with the chemical composition of the base metal and other conditions of intended use. Inserts must be approved for use by the Project Engineer.

3-221. PURGING.

**WARNING**

To prevent injury to personnel, the immediate area in which welding is being performed when using argon or helium gas shall be adequately ventilated. If adequate ventilation cannot be provided, personnel performing the welding operation shall wear breathing apparatus of a type approved by Ground Safety and Industrial Hygiene and the Welding Supervisor.

3-222. Joints to be welded with the inert gas shielded tungsten arc process shall have the weld joint root protected by a shielding or purging atmosphere of inert gas, using a suitable purging attachment which will maintain the purging gas for a distance of six to ten inches on each side of the joint. The methods used for purging piping and/or systems shall be approved by the Project Engineer.

3-223. Pipe shall be purged before welding is started, and purging shall be maintained throughout the entire welding operation. When conditions permit, the purging gas should be introduced at the lowest point in the pipe or system and vented out at the high points. Oxidation of weld deposits and/or base metal is not permitted.

3-224. STARTING THE ARC.

3-225. Whenever possible, the arc shall be started by a high-frequency arc starter attachment. The high-frequency current shall be sufficient to start the arc without touching the electrode to the workpiece. If the high-frequency arc starter is not available, a copper starting pad firmly attached to the workpiece adjacent to the weld joint may be used. The electrode may be struck on the copper pad to start the arc, and the arc can then be moved to the weld zone. Under no conditions shall the arc be struck on the surface of the base metal outside of the weld joint.

3-226. BREAKING THE ARC.

3-227. The preferred method for breaking the arc shall be to extinguish the arc by use of a foot-operated current control to decrease the welding current gradually until the arc will travel without fusing the base metal. If the foot-operated current control is not available, the rate of travel shall be increased to a speed at which the arc will travel without fusing the base metal, and the arc can then be broken.

3-228. ELECTRICAL CHARACTERISTICS.

3-229. Welding of carbon steels, stainless steels, nickel alloys, and ferrous metals shall be performed using direct current and straight polarity (electrode negative).

3-230. Welding of aluminum shall be performed using alternating current with superimposed high frequency.

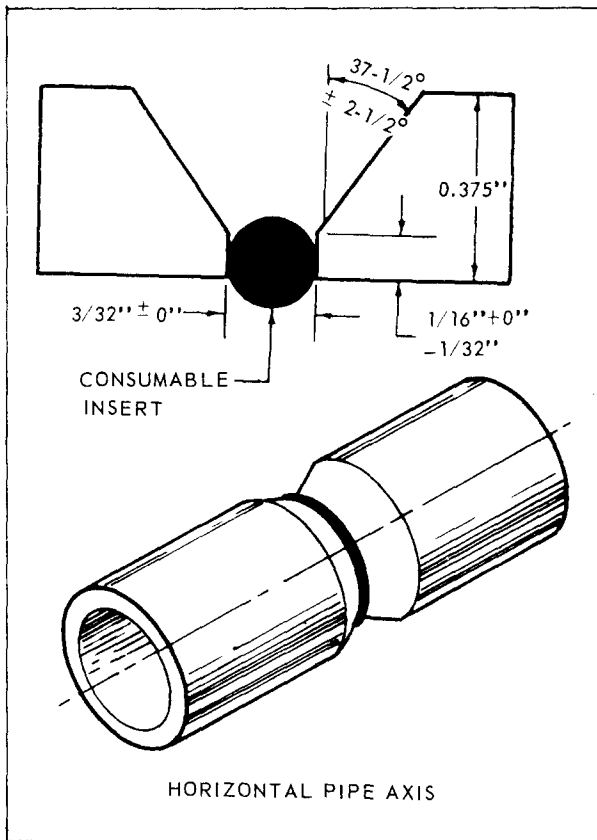


Figure 3-5. Weldment with Consumable Insert - Horizontal Attitude

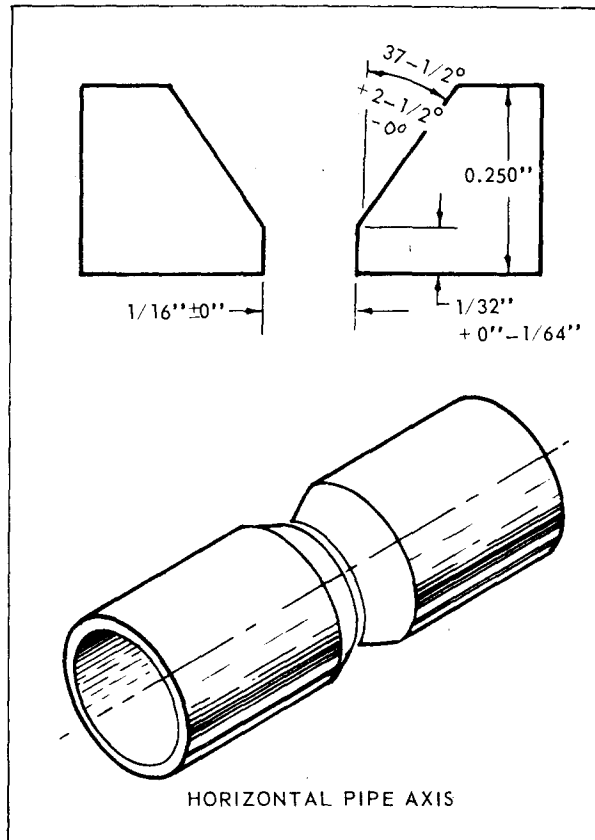


Figure 3-7. Weldment of Thirty-six Percent Nickel Low Expansion Alloy - Horizontal Attitude

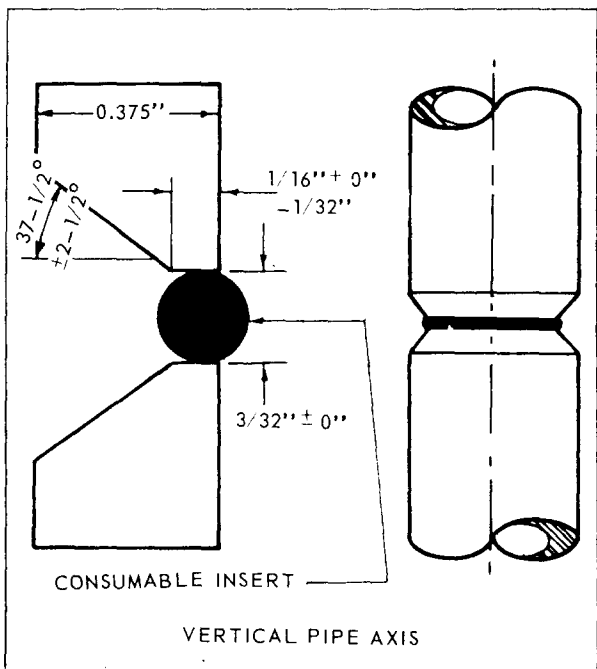


Figure 3-6. Weldment with Consumable Insert - Vertical Attitude

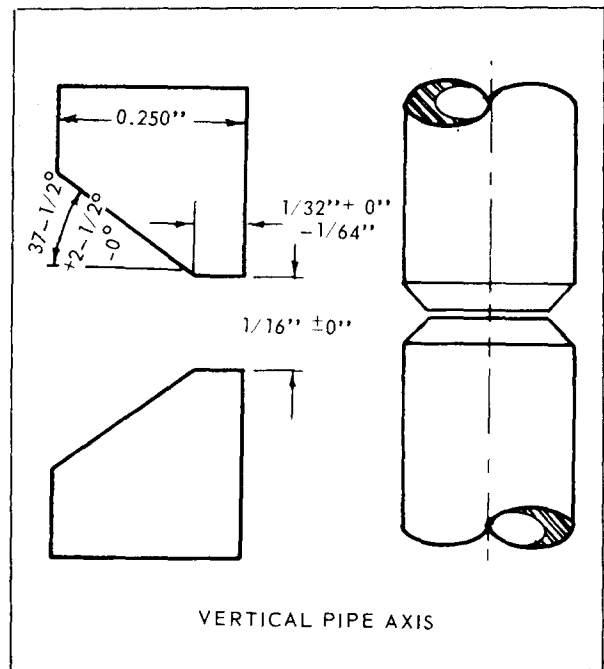


Figure 3-8. Weldment of Thirty-six Percent Nickel Low Expansion Alloy - Vertical Attitude

3-231. FIRST PASS WITH ROOT OPENING. (Figures 3-1 and 3-2).

3-232. The first welding pass shall be performed by adding filler metal as required to bridge the opening and weld the two lands together. The filler metal shall be deposited in such a manner that the two edges being joined and the filler metal flow together until one continuous piece of sound, homogenous metal is formed when the molten metal has solidified. No filler metal shall be added until the base metal is in a molten state.

3-233. FIRST PASS WITH NO ROOT OPENING. (Figures 3-3 and 3-4).

3-234. The first welding pass shall be performed using the fusion method with no filler metal added. Fusion welding shall be such that the molten metal from the two edges being joined will flow together until one continuous piece of sound, homogenous metal is formed when the molten metal has solidified.

3-235. FIRST PASS WITH CONSUMABLE INSERT. (Figures 3-5 and 3-6).

3-236. The first welding pass shall be performed using the fusion method with no filler metal added. Fusion welding of the consumable insert shall be such that the molten metal from the insert and the two edges being joined shall flow together until one continuous piece of sound, homogenous metal is formed when the molten metal has solidified.

3-237. The welding technique and manner of depositing the root weld shall be such as to insure full penetration for the full length of the joint. The weld metal deposit shall be uniform and free of all defects.

3-238. After the first welding pass is completed, the subsequent passes shall be deposited by adding filler metal as required to complete the weld joint.

3-239. CONTROLS.

3-240. Weaving of the electrode shall be carefully controlled so that the molten pool of metal is adequately protected by the shielding gas at all times. To prevent oxidation of the weld surface, the welding torch shall be held at an angle which will direct the inert-gas flow over the deposited metal as it cools from red to a black heat indication.

3-241. The hot filler rod shall not be withdrawn from the shielding inert-gas atmosphere while welding is in progress or before the welding rod has cooled sufficiently to prevent oxidation of the rod. When there is evidence of oxidation on a welding rod, the rod shall be trimmed or cut back to dispose of all oxidized material. This may be accomplished by using a wire-cutter or other suitable means. Oxidized materials shall not be introduced into the weldmelt.

3-242. MANUAL OXY-ACETYLENE WELDING PROCESS.

3-243. SAFETY.

**WARNING**

All safety precautions, paragraphs 3-6 thru 3-23, shall be observed when doing manual oxy-acetylene welding. Refer to T.O. 42B5-1-2 for details of safety precautions in using and handling compressed gas cylinders.

3-244. Eye protection for Oxy-Acetylene welding and cutting operations shall be as follows:

- a. Shade No. 5 filter lens for light gas cutting and welding.
- b. Shade No. 6 for medium gas cutting and welding.
- c. Shade No. 8 for heavy gas welding.

3-245. To minimize the danger of fire and serious painful burns, extreme care shall be exercised in Oxy-Acetylene welding and cutting operations. The flame shall always be kept within the welder's field of vision and shall not be allowed to contact any part of the welding equipment.

3-246. When not in use, the torch shall be extinguished and its control valves turned off. When the torch is out of use for an extended period of time the tank valves shall be shut off. The lighted torch shall not be pointed at concrete surfaces. When flashback occurs, both torch valves shall be immediately closed. If a hose bursts, or escaping gas ignites at the tank, regulator controls will be turned off at once.

3-247. Torch valves, hose, etc., shall be inspected prior to use.

### 3-248. REQUIREMENTS.

3-249. The procedures outlined in paragraphs 3-250 through 3-271 are those for welding carbon steel pipe, using the oxy-acetylene method. To obtain optimum results, these procedures shall be adhered to without deviations except as permitted by the Design Engineer.

### 3-250. WELDING EQUIPMENT.

3-251. Oxy-acetylene torches, tips, regulators, and associated equipment shall be of standard manufacture, and shall be suitable for the conditions of the intended use. Oxy-acetylene equipment shall be approved by the Project Engineer. Equipment found to be defective shall not be used for any purpose.

3-252. Oxy-acetylene torches, tips and regulators are used to form and control the welding flame and to apply a suitable flame at a predetermined location.

3-253. There shall always be a logical relationship between the sizes of welding tips and the metal thicknesses. This relationship has been determined by practical applications. The thickness of steel which is to be welded is plotted against the tip size, and the tip sizes are determined by the diameter of the orifice.

3-254. When a series of welding tips are selected for various thicknesses of metal, the thickness range covered by a given tip should slightly overlap the range covered by the next tip in the series.

3-255. Recommendations of the manufacturer of the equipment shall be followed in all cases.

### 3-256. TECHNIQUES.

#### **WARNING**

To prevent injury to personnel, all gas cylinders (oxy-acetylene) etc; shall be secured in an upright position; under no conditions shall cylinders be used while placed in a position other than upright. All connections to tank valves, regulators, hoses, and torches shall be made up tight and free from leaks.

3-257. When performing oxy-acetylene welding, there is an ever-present problem of maintaining the neutral character of the gas shield. This demands accurate proportioning of oxygen and acetylene during mixing in order to avoid an excess of one or the other. Excess oxygen leads to weld porosity; excess acetylene promotes reducing (carburizing) conditions resulting in carbon build-up in the weld zone. The added carbon from a reducing flame may result in a total content in excess of that which was originally intended. Carbon pickup increases the hardening characteristics of the materials.

3-258. The chemical action of the flame on a molten pool of metal can be altered by changing the ratio of the volume of oxygen to acetylene issuing from the tip.

3-259. The length of the flame will vary with the volume of gases issuing from the tip; the inner cone will attain a length of approximately one inch for large flames. The action of the oxy-acetylene flame on the base material being heated can be made soft, or harsh and violent, by varying the gas flow. Practical limitations shall govern the types of flame to be used. A harsh or oxidizing flame will cause the molten metal to be blown from the weld puddle, and an excessively soft flame is not stable near the point of application.

3-260. Compared to fusion methods employing the electric arc as the heat source, oxy-acetylene welding is slower. The flame temperature is lower, and the production of heat is less concentrated. While the heating effect reaches a maximum at the inner cone of the flame, the surrounding volume of hot burning gas spreads into the adjacent metal, and results in elevated temperatures over relatively wide areas adjacent to the point of fusion.

3-261. Oxy-acetylene welding shall be performed with torch tip pointed forward in the direction in which the welding progresses. This method is known as the forehand technique, and shall be used at all times. Inclination of the torch shall be sixty to seventy five degrees to the line of the joint being welded.

3-262. Pointing the torch tip in the direction to be followed along the line of the joint places the edges to be joined under protection of the gas atmosphere, and also serves as a preheating agent. This positioning speeds up the cooling rate of the weld zone behind the torch tip.

3-263. In manual operation, the torch shall be manipulated so as to bring the inner cone of the flame to the base metal, and provide maximum heating at the point of intended fusion.

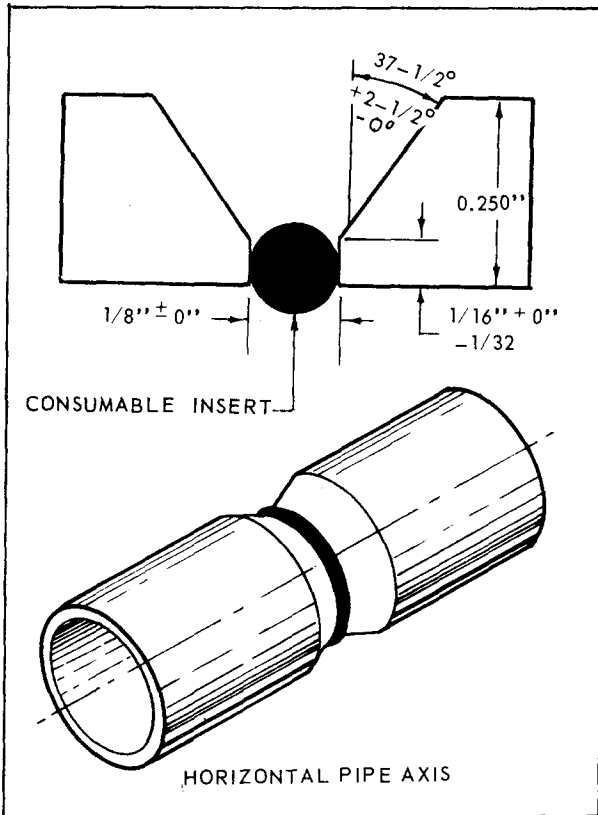


Figure 3-9. Weldment of Thirty-six Percent Nickel Low-Expansion Alloy with Consumable Insert - Horizontal Attitude

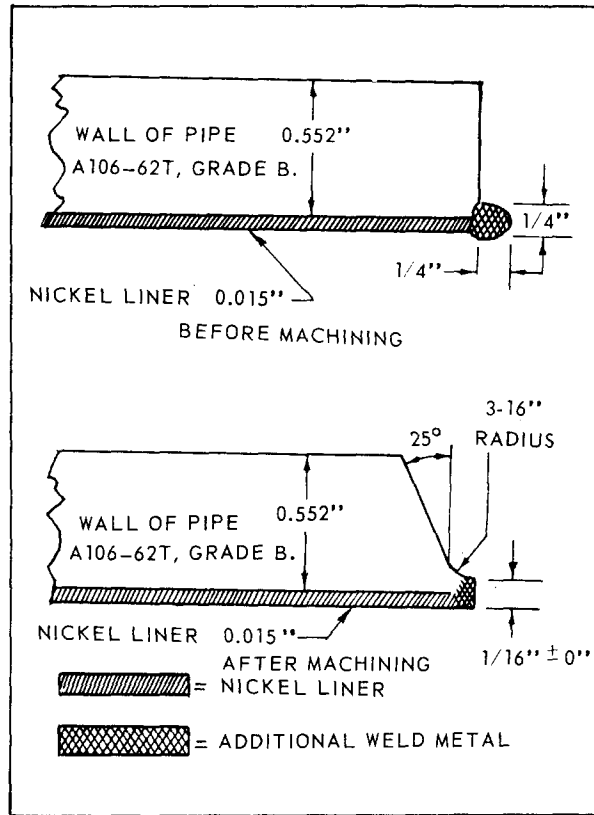


Figure 3-11. Edge Preparation, Grade B Nickel-Lined Pipe

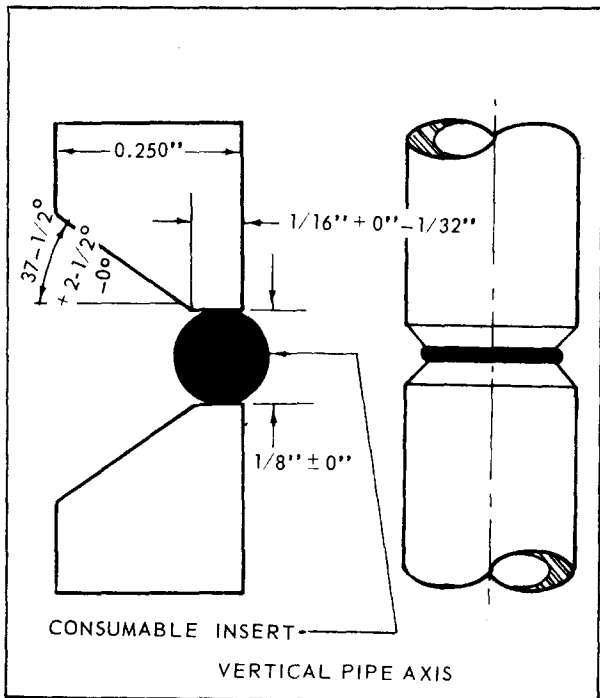


Figure 3-10. Weldment of Thirty-six Percent Nickel Low-Expansion Alloy with Consumable Insert - Vertical Attitude

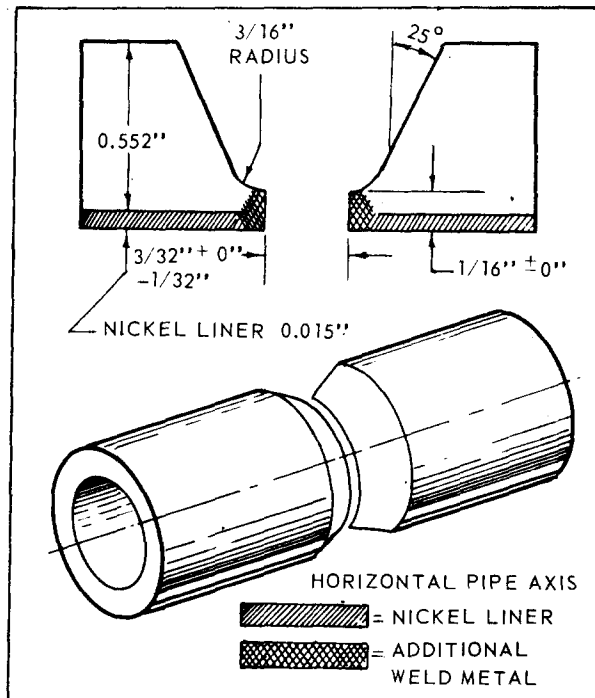


Figure 3-12. Weldment of Grade B Nickel-Lined Pipe - Horizontal Attitude

3-264. When welding joints of unequal thicknesses, the welding flame shall be directed in such manner that both pieces being welded are heated to identical temperatures.

3-265. Weld metal shall be deposited in such manner that the molten metal from the two edges to be joined and the filler metal being added, shall flow together until one continuous piece of metal is formed when the molten metal has solidified.

#### 3-266. WELDING FLAME.

3-267. The welding flame to be used for a specific welding operation shall be as recommended by the manufacturer of the base metal and filler metal being used.

3-268. The welding flame for carbon steel shall be properly adjusted to a neutral flame (approximately a one-to-one gas ratio) and shall remain in that condition throughout the welding operation; under no conditions shall an oxidizing flame be used.

3-269. The size of the welding tip shall be adequate to maintain the proper welding temperature in the base metal, and obtain a continuity of weld deposit without interruption of the welding operation.

#### 3-270. POSTHEAT TREATMENT.

### CAUTION

Postheating shall be performed only as described in paragraph 3-271. To prevent damage to the material being welded, postheating of weld deposits or base metal to straighten or align a weldment is not permissible.

3-271. After welding of the joint is completed, the weld deposit and adjoining base metal shall be heated for a distance of three inches on each side of the joint to a maximum of 300°F, and allowed to cool in still air.

#### 3-272. THIRTY-SIX PERCENT NICKEL-LOW-EXPANSION ALLOY WELDING PROCEDURE.

### WARNING

All safety precautions previously given for arc welding and for handling of gas shall be followed when welding 36% nickel.

#### 3-273. REQUIREMENTS.

3-274. Welding 36% nickel low-expansion alloy, using the manual inert-gas shielded tungsten arc process alone, or combined with the manual metal arc process, shall be performed in accordance with the specific requirements of paragraphs 3-275 through 3-301 and the general requirements of paragraphs 3-144 through 3-241.

#### 3-275. MATERIAL CHARACTERISTICS.

3-276. The austenitic alloys of the iron-nickel type provide a wide range of specialized thermal, electrical, mechanical, magnetic, and other properties.

3-277. This alloy has been used for years in applications requiring maximum low expansion, or those requiring specific expansion characteristics. However, it has only been recently that this material has been introduced to heavy industry and such usages as are applicable to this manual.

3-278. No significant metallurgical change occurs in the heat-affected zone during welding. A slight amount of grain may be evidenced across a narrow band, but no other change occurs.

3-279. The fluidity of molten 36% nickel low-expansion alloy is less than that of steel. Consequently, closely maintained control of the molten base metal and filler metal is required during the welding operation. Preparation of the bevels and fitting up of parts shall be in accordance with Figures 3-7 through 3-10, as applicable.

3-280. To acquaint the operator with 36% nickel low-expansion alloy, and consequently facilitate the welding process, information regarding composition, mechanical properties, expansion, and the melting point are provided in paragraphs 3-279 through 3-285.

3-281. Material Composition. The following presents a typical chemical composition of 36% nickel low-expansion alloy:

<u>Material</u>	<u>Percentage</u>
Carbon	0.12 (Max)
Manganese	1.00
Silicon	0.35 (Max)
Nickel and Cobalt	36.00
Iron	Remainder

3-282. Mechanical Properties. The following presents typical annealed and cold-drawn mechanical properties of 36% nickel low-expansion alloy:

<u>Mechanical Properties</u>	<u>Annealed</u>	<u>Cold-Drawn</u>
Tensile Strength	65,000 psi	90,000 psi
Yield Point	40,000 psi	70,000 psi
Reduction of Area	65%	60%
Elongation in 2 Inches	35%	20%
Hardness (Brinell)	125	105
Hardness (Rockwell)	B-70	B-90

3-283. Expansion. The expansion rate of 36% nickel low-expansion alloy is approximately 1/10 of that for ordinary carbon steel (containing approximately 3/10% carbon) but this expansion rate is present only through the temperature range of -100°F to approximately 375°F. Above 375°F, the expansion rate increases rapidly, and above 530°F, the expansion rate is equal to that of carbon steel; this is known as the inflection point. At approximately 850°F, the expansion rate exceeds that of carbon steel; however, the total expansion from -100°F to any given higher temperature will be less than the total expansion for carbon steel.

3-284. Magnetic Inversion. Magnetic inversion of 36% nickel low-expansion alloy occurs at 530°F; the alloy is magnetic at lesser temperatures, and is non-magnetic at greater temperatures. Resultantly, the alloy is always magnetic in the temperature range in which it exhibits the low-expansion characteristics.

3-285. Melting Point. The melting point of this alloy is 2600°F. At 1000°F, the alloy exhibits the first indication of softening; the softening continues progressively to 2300°F. Grain growth does not occur until the temperature exceeds 1900°F.

3-286. Fusion Method. Due to the inherent characteristic of the alloy, fusion welding without the addition of filler metal may cause excessive porosity, and should be avoided.

3-287. Filler Metal.

3-288. Inasmuch as this alloy has only recently been introduced to heavy industrial applications; Military Specifications, Federal Standards, or ASTM Specifications are not available at this time for the filler metal to be used when performing manual inert-gas shielded tungsten-arc welding.

3-289. A weld wire, containing the following chemicals (in the proportions noted) is commercially available, and is acceptable for use as a filler metal.

<u>Chemical</u>	<u>Percentage</u>
Carbon	0.10
Manganese	3.29
Silicon	0.09
Sulphur	0.012
Phosphorous	0.003
Nickel	36.19
Molybdenum	0.05
Titanium	0.94
Lead	0.001
Iron	Remainder

### 3-290 TEMPERATURE CONTROL.

3-291. In all welding processes described in this manual involving this alloy, the operator must recognize that the expansivity of the base metal is dependent upon the temperature range during the weldment. Control of the maximum temperature is of the utmost importance in that it establishes the upper temperature limits at which inflection occurs, and the temperature of the base metal at the weld zone.

3-292. Cooling Procedures. The method of cooling utilized during a welding procedure can provide an effective means of controlling alloy expansion. Rapid cooling decreases the rate of expansion; slow cooling has the reverse effect. The 36% nickel low-expansion alloy may be air-cooled or water-quenched to interpass temperature, provided the specific cooling procedure is approved by the Project Engineer, and that all traces of moisture are removed before additional metal is added.

3-293. Interpass Temperatures.

3-294. Interpass temperatures of the weld metal shall be such that expansion and contraction of the weldment shall be held to a minimum to prevent high stresses that may cause weld cracks or subsequent failures.

3-295. To avoid excessive or residual stresses, the interpass temperature shall not exceed 250°F, nor be less than 70°F while fabrication is in progress, or before the weldment is completed. Each pass of weld deposit shall be allowed to cool to 300°F before the next successive pass of welding is started.



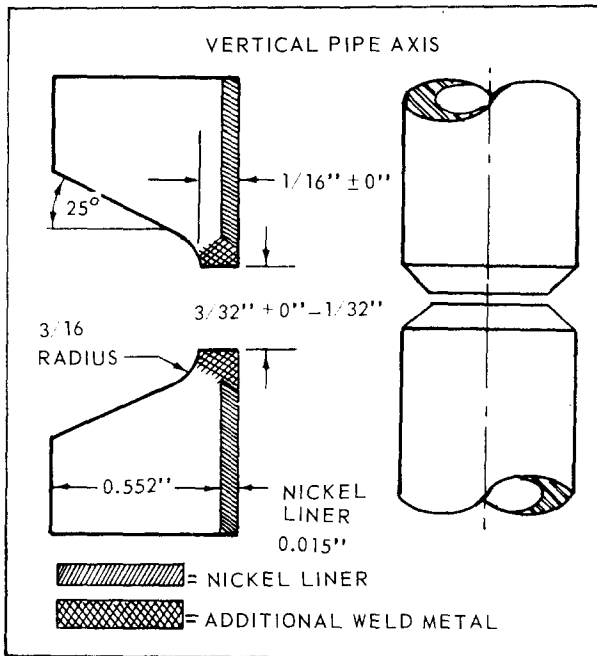


Figure 3-13. Weldment of Grade B Nickel-Lined Pipe - Vertical Attitude

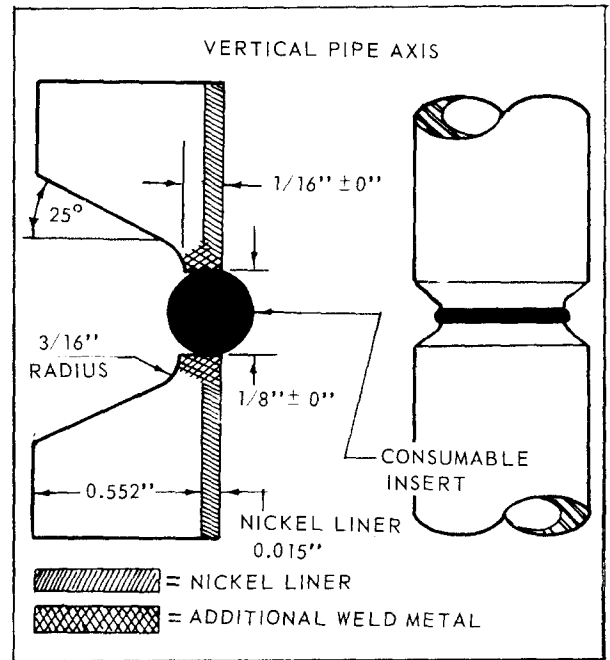


Figure 3-15. Weldment of Grade B Nickel-Lined Pipe with Consumable Insert - Vertical Attitude

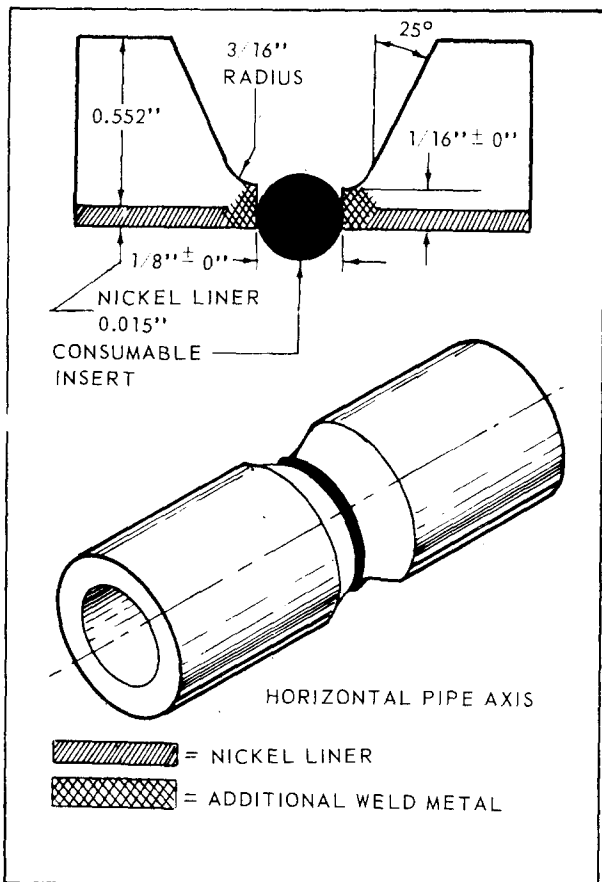


Figure 3-14. Weldment of Grade B Nickel-Lined Pipe with Consumable Insert - Horizontal Attitude

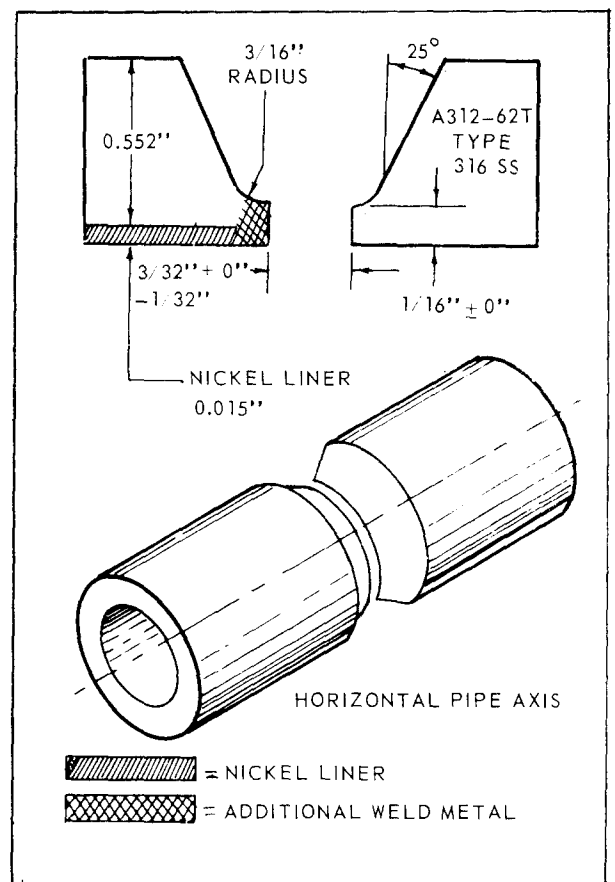


Figure 3-16. Weldment of Grade B Nickel-Lined Pipe to Dissimilar Metal - Horizontal Attitude

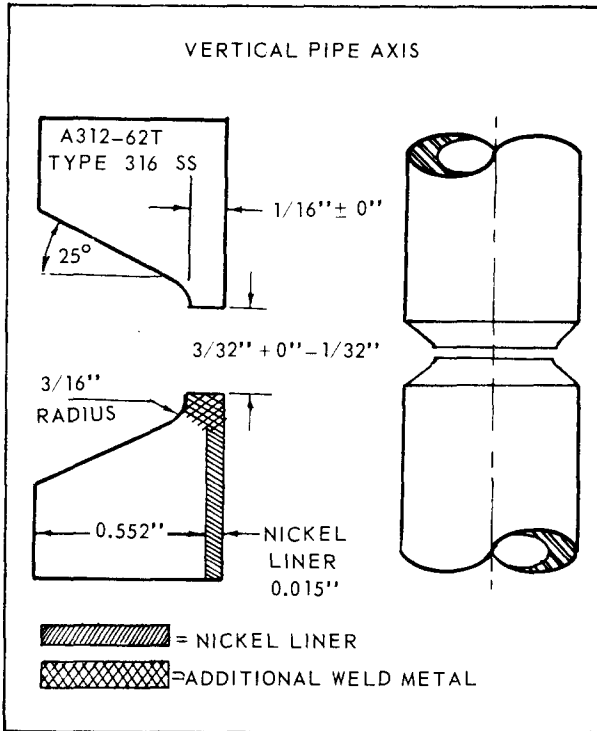


Figure 3-17. Weldment of Grade B Nickel-Lined Pipe to Dissimilar Metal - Vertical Attitude

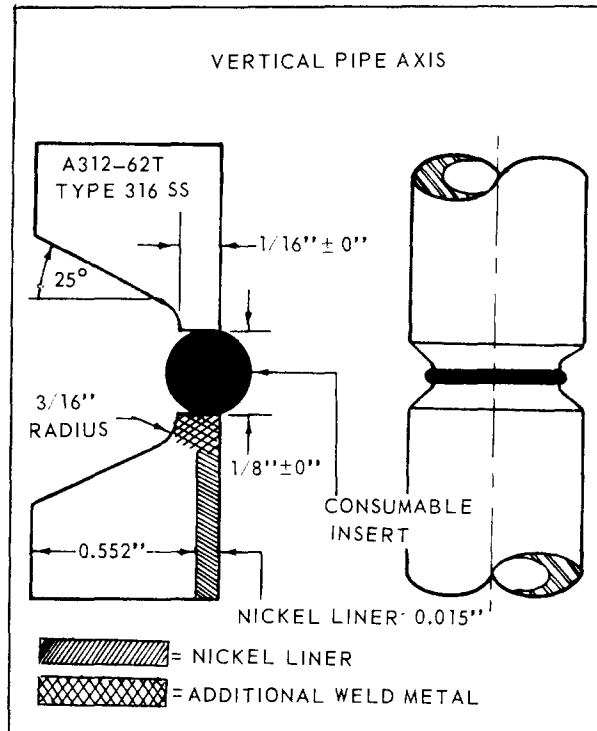


Figure 3-19. Weldment of Grade B Nickel-Lined Pipe to Dissimilar Metal with Consumable Insert - Vertical Attitude

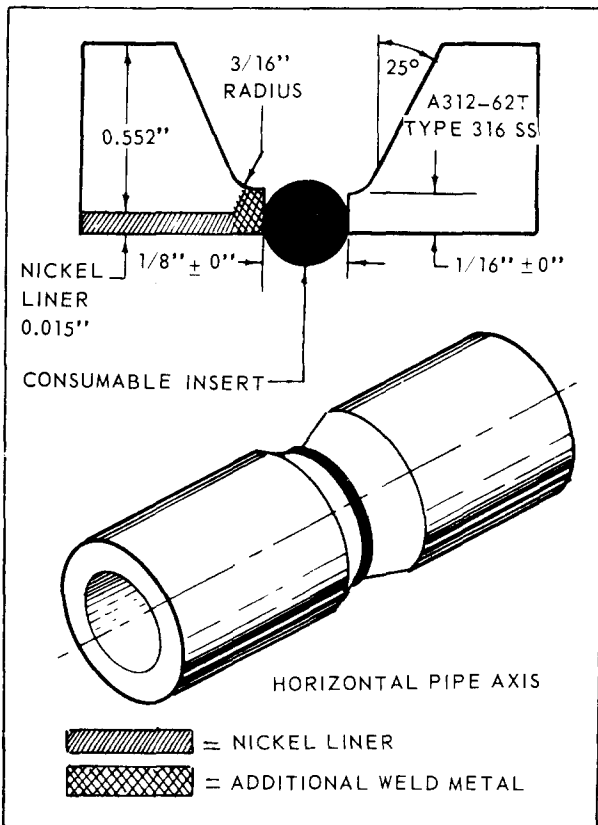


Figure 3-18. Weldment of Grade B Nickel-Lined Pipe to Dissimilar Metal with Consumable Insert - Horizontal Attitude

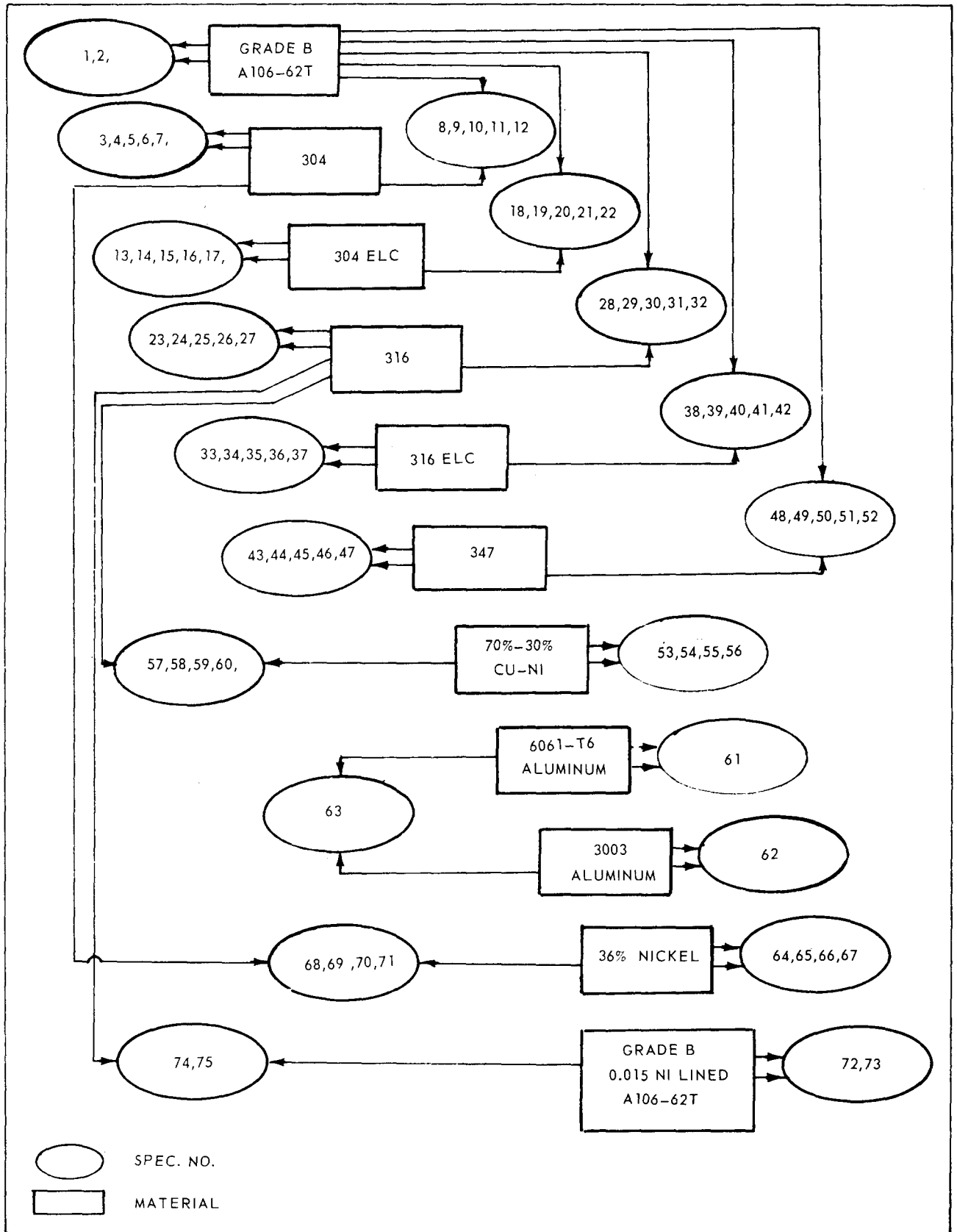


Figure 3-20. Material(s) / Specification(s) Quick-Reference Chart

3-296. WELDING 36 PERCENT NICKEL LOW-EXPANSION ALLOY TO DISSIMILAR METALS.

**WARNING**

All safety precautions previously given for arc welding and handling of gas shall be complied with in this process.

3-297. In the process of joining this alloy to a material having high-expansivity characteristics (such as the 300-series stainless steels) the relative movement between parts, which occurs with change of temperature, will cause a high degree of differential dimensional change.

3-298. Jigs, fixtures, and external supports shall be placed and affixed in such a manner that normal movement of the parts being joined shall not be restricted; thereby creating excessive or residual stresses in the base metals and the weld metal.

3-299. Welding 36% low-expansion alloy to itself and to dissimilar metals is a highly specialized operation, requiring strict adherence to the data provided in the respective Qualification Procedures (see figures 3-146 to 3-161, as applicable). This data shall be observed and utilized to the extent that all requirements of the applicable procedures are incorporated in the completed welds. No deviations shall be permitted without specific approval of the Project Engineer.

**WARNING**

To prevent injury, impact-type goggles or face shield shall be worn by personnel when engaged in grinding and buffing operations.

3-300. GRINDING.

3-301. Grinding wheels shall be silicon carbide, or equal. A soft wheel, which will wear without undue loading of the stone, is preferred for rough grinding; the finish grinding wheel should be approximately No. 80 grit. Wire brushes used for cleaning shall be stainless steel. Grinding wheels and wire brushes shall not have been previously used on other materials.

3-302. GRADE B NICKEL-LINED PIPE.

**WARNING**

All safety precautions previously given for arc welding and handling of gas shall be followed when welding grade B nickel-lined pipe.

3-303. REQUIREMENTS.

3-304. Welding Grade B nickel-lined pipe, using the manual metal arc process alone, or combined with the manual inert-gas shielded tungsten arc process, shall be performed in accordance with the specific requirements of paragraphs 3-305 through 3-311 and the general requirements of paragraphs 3-144 through 3-241.

3-305. EDGE PREPARATION.

3-306. Prior to machining bevels on pipe ends, the area of the nickel liner to the steel pipe shall be prepared by depositing the specified filler metal as required to obtain a homogenous seal of weld metal in the juncture of the nickel liner to the steel pipe.

3-307. The additional buildup of weld metal shall be sufficient to provide a land or welding edge. Figure 3-11 specifies the minimum dimensions for the additional weld metal, and the type and contour of bevel to be machined on pipe ends.

3-308. FITTING UP JOINTS.

3-309. Fitting up butt joints with a root opening shall be performed in accordance with Figures 3-12 and 3-13.

3-310. Fitting up butt joints with a consumable insert shall be in accordance with Figures 3-14 and 3-15.

3-311. Fitting up butt joints when welding Grade B nickel-lined pipe to dissimilar metals shall be in accordance with Figures 3-16 through 3-19, as applicable.

3-312. SPECIFICATIONS.

3-313. GENERAL. The welding procedures and the materials used in these processes are listed below with the applicable specification number. Figure 3-20 presents a diagram to provide a quick reference to the applicable specification for each base metal or combination thereof. Paragraphs 3-315 through 3-320 present detailed specifications of these procedures.

Specification No.	Title
1.	Manual Metal Arc, Carbon Steel.
2.	Manual Oxy-Acetylene, Carbon Steel.
3.	Manual Metal Arc, Stainless Steel (Type 304).

Specification No.	Title	Specification No.	Title
4.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 304).	17.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 304 ELC).
5.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 304).	18.	Manual Metal Arc, Stainless Steel (Type 304 ELC) and Carbon Steel.
6.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 304).	19.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 304 ELC) and Carbon Steel.
7.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 304).	20.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 304 ELC) and Carbon Steel.
8.	Manual Metal Arc, Stainless Steel (Type 304) and Carbon Steel.	21.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 304 ELC) and Carbon Steel.
9.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 304) and Carbon Steel.	22.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 304 ELC) and Carbon Steel.
10.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 304) and Carbon Steel.	23.	Manual Metal Arc, Stainless Steel (Type 316).
11.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 304) and Carbon Steel.	24.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 316).
12.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 304) and Carbon Steel.	25.	Manual Inert-Gas Shielded Tungsten Arc, and Manual Metal Arc, Stainless Steel (Type 316).
13.	Manual Metal Arc, Stainless Steel (Type 304 ELC).	26.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 316).
14.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 304 ELC).	27.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 316).
15.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 304 ELC).	28.	Manual Metal Arc, Stainless Steel (Type 316) and Carbon Steel.
16.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 304 ELC).		

Specification No.	Title	Specification No.	Title
29.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 316) and Carbon Steel.	41.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 316 ELC) and Carbon Steel.
30.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 316) and Carbon Steel.	42.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert Stainless Steel (Type 316 ELC) and Carbon Steel.
31.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 316) and Carbon Steel.	43.	Manual Metal Arc, Stainless Steel (Type 347).
32.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 316) and Carbon Steel.	44.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 347).
33.	Manual Metal Arc, Stainless Steel (Type 316 ELC).	45.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc Stainless Steel (Type 347).
34.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 316 ELC).	46.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 347).
35.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 316 ELC).	47.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 347).
36.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 316 ELC).	48.	Manual Metal Arc, Stainless Steel (Type 347) and Carbon Steel.
37.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 316 ELC).	49.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 347) and Carbon Steel.
38.	Manual Metal Arc, Stainless Steel (Type 316 ELC) and Carbon Steel.	50.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 347) and Carbon Steel.
39.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 316 ELC) and Carbon Steel.	51.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 347) and Carbon Steel.
40.	Manual Inert-Gas Shielded Tungsten Arc, and Manual Metal, Arc, Stainless Steel (Type 316 ELC) and Carbon Steel.	52.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 347) and Carbon Steel.

Specification No.	Title	Specification No.	Title
53.	Manual Inert-Gas Shielded Tungsten Arc, 70-30 Copper-Nickel.	65.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, 36% Nickel Low-Expansion Alloy.
54.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, 70-30 Copper-Nickel.	66.	Manual Inert-Gas Shielded Tungsten Arc, 36% Nickel Low-Expansion Alloy, with Consumable Insert.
55.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, 70-30 Copper-Nickel.	67.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, 36% Nickel Low-Expansion Alloy with Consumable Insert.
56.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, with Consumable Insert 70-30 Copper-Nickel.	68.	Manual Inert-Gas Shielded Tungsten Arc, 36% Nickel Low-Expansion Alloy and Stainless Steel (Type 304).
57.	Manual Inert-Gas Shielded Tungsten Arc, Stainless Steel (Type 316) and 70-30 Copper-Nickel.	69.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, 36% Nickel Low-Expansion Alloy and Stainless Steel (Type 304).
58.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Stainless Steel (Type 316) and 70-30 Copper-Nickel.	70.	Manual Inert-Gas Shielded Tungsten Arc, 36% Nickel Low-Expansion Alloy and Stainless Steel (Type 304) with Consumable Insert.
59.	Manual Inert-Gas Shielded Tungsten Arc with Consumable Insert, Stainless Steel (Type 316) and 70-30 Copper-Nickel.	71.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, 36% Nickel Low-Expansion Alloy and Stainless Steel (Type 304) with Consumable Insert.
60.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc with Consumable Insert, Stainless Steel (Type 316) and 70-30 Copper-Nickel.	72.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Carbon Steel with 0.015 Nickel Liner.
61.	Manual Inert-Gas Shielded Tungsten Arc, Aluminum (Type 6061-T6).	73.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Carbon Steel with 0.015 Nickel Liner and Consumable Insert.
62.	Manual Inert-Gas Shielded Tungsten Arc, Aluminum (Type 3003).	74.	Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Carbon Steel with 0.015 Nickel Liner and Stainless Steel (Type 316).
63.	Manual Inert-Gas Shielded Tungsten Arc, Aluminum (Type 6061-T6) and Aluminum (Type 3003).		
64.	Manual Inert-Gas Shielded Tungsten Arc, 36% Nickel Low-Expansion Alloy.		

Title

75. Manual Inert-Gas Shielded Tungsten Arc and Manual Metal Arc, Carbon Steel with 0.015 Nickel Liner and Stainless Steel (Type 316) with Consumable Insert.

3-320. TABULAR INFORMATION. The designators in the MATERIAL and FILLER METAL columns of Figure 3-21 are those supplied by the American Society for Testing Materials (ASTM). For the convenience of the user, the following cross-reference material is provided:

3-314. SPECIFIC WELDING PROCEDURE SPECIFICATIONS. The following paragraphs contain the detailed specification for each of the welding procedures described in paragraph 3-313. These specifications, in tabular form (see figure 3-21), specify the material (s) , filler metal (s) , welding process, procedure, and certification of test data.

3-315. MATERIAL.

3-316. The material (s) shall be the specified metal(s) for the subject weldment, and shall be detailed in the MATERIAL column of Figure 3-21.

3-317. FILLER METAL. The filler metal (s) shall be those specified for the subject weldment and shall be detailed in the FILLER METAL column of Figure 3-21.

3-318. PROCESS. The process shall be the specified method to accomplish the subject weldment, and shall be detailed in the PROCESS column of Figure 3-21.

3-319. CERTIFICATION OF TEST DATA. The certification of test data shall be the certification of the optimum mechanical properties of the subject weldment, and shall be detailed in the CERTIFICATION column of Figure 3-21 by reference to the applicable figure numbers.

<u>ASTM Designator</u>	<u>Military/Federal Specification</u>
<b>MATERIAL</b>	
A106-62T	No applicable specification
A312-62T, Type 304	MIL-T-18063
A312-62T, Type 304L	MIL-T-18063
A312-62T, Type 316	MIL-P-1144A
A312-62T, Type 316L	MIL-T-1144A
A312-62T, Type 347	MIL-T-18063
B111-61T	MIL-T-15005B
B241-55T, GS11A	MIL-T-7081A
B241-55T, M1A	WW-T-788C

**FILLER METAL**

A233-58T	MIL-E-15599C
A251-46T	MIL-R-908
A298-62T	MIL-E-22200
A371-62T	MIL-R-5031A
B259-57T	QQ-R-571A
B225-57T	MIL-E-19323A
B285-61T	QQ-R-566



SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
1	A106-62T	Grade B Welded to Grade B	A233-58T	E6010	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-22
2	A106-62T	Grade B Welded to Grade B	A251-46T	GA60	Manual Oxy- Acetylene	Paragraphs 3-242 through 3-271	Figure 3-23
3	A312-62T	304 Welded to 304	A298-62T	ER308-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-24
4	A312-62T	304 Welded to 304	A371-62T	ER308	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-25
5	A312-62T	304 Welded to 304	A371-62T and A298-62T	ER308 and ER308-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-26
6	A312-62T	304 Welded to 304, using consumable insert	A371-62T	ER308	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-27
7	A312-62T	304 Welded to 304, using consumable insert	A371-62T and A298-62T	ER308 and ER308-15	Manual Inert-Gas Shielded Tung- sten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-28
8	A312-62T and A106-62T	304 Welded to Grade B	A298-62T	E310-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-29
9	A312-62T and A106-62T	304 Welded to Grade B	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-30

Figure 3-21. Detailed Welding Procedure (Sheet 1 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
10	A312-62T and A106-62T	304 Welded to Grade B	A371-62T and A298-62T	ER310 and ER310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-31
11	A312-62T and A106-62T	304 Welded to Grade B, using consumable insert	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-32
12	A312-62T and A106-62T	304 Welded to Grade B using consumable insert	A371-62T and A298-62T	ER310 and ER310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass)	Paragraphs 3-144 through 3-241	Figure 3-33
13	A312-62T	304 ELC Welded to 304 ELC	A298-62T	E308L-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-34
14	A312-62T	304 ELC Welded to 304 ELC	A371-62T	ER308L	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-35
15	A312-62T	304 ELC Welded to 304 ELC	A371-62T and A298-62T	ER308-L and E308L-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-36
16	A312-62T	304 ELC Welded to 304 ELC, using consumable insert	A371-62T	ER308L	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-37
17	A312-62T	304 ELC Welded to 304 ELC, using consumable insert	A371-62T and A298-62T	ER308L and E308L-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-38

Figure 3-21. Detailed Welding Procedures (Sheet 2 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
18	A312-62T and A106-62T	304 ELC Welded to Grade B	A298-62T	E310-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-39
19	A312-62T and A106-62T	304 ELC Welded to Grade B	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-40
20	A312-62T and A106-62T	304 ELC Welded to Grade B	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-41
21	A312-62T and A106-62T	304 ELC Welded to Grade B, using consumable insert	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-42
22	A312-62T and A106-62T	304 ELC Welded to Grade B, using consumable insert	A371-62T and A298-62T	ER310 and ER310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-43
23	A312-62T	316 Welded to 316	A298-62T	E316-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-44
24	A312-62T	316 Welded to 316	A371-62T	ER316	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-45
25	A312-62T	316 Welded to 316	A371-62T and A298-62T	ER316 and E316-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) (Continued)	Paragraphs 3-144 through 3-241	Figure 3-46

Figure 3-21. Detailed Welding Procedure (Sheet 3 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
25 (cont.)					Manual Metal Arc (subsequent passes)		
26	A312-62T	316 Welded to 316, using consumable insert	A371-62T	ER316	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-47
27	A312-62T	316 Welded to 316, using consumable insert	A371-62T and A298-62T	ER316 and E316-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-48
28	A312-62T and A106-62T	316 Welded to Grade B	A298-62T	E310-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-49
29	A312-62T and A106-62T	316 Welded to Grade B	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-50
30	A312-62T and A106-62T	316 Welded to Grade B	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-51
31	A312-62T and A106-62T	316 Welded to Grade B, using con- sumable insert	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-52
32	A312-62T and A106-62T	316 Welded to Grade B using con- sumable in- sert	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) (Continued)	Paragraphs 3-144 through 3-241	Figure 3-53

Figure 3-21. Detailed Welding Procedure (Sheet 4 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
32 (cont.)					Manual Metal Arc (subsequent passes)		
33	A312-62T	316 ELC Welded to 316 ELC	A298-62T	E316L-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-54
34	A312-62T	316 ELC Welded to 316 ELC	A371-62T	ER316L	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-55
35	A312-62T	316 ELC Welded to 316 ELC	A371-62T and A298-62T	ER316L and E316L-15	Manual Inert-Gas Shielded Tungsten Arc (first pass)  Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-56
36	A312-62T	316 ELC Welded to 316 ELC, using con- sumable insert	A371-62T	ER316L	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-57
37	A312-62T	316 ELC Welded to 316 ELC, using con- sumable insert	A371-62T and A298-62T	ER316L and E316L-15	Manual Inert-Gas Shielded Tungsten Arc (first pass)  Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-58
38	A312-62T and A106-62T	316 ELC Welded to Grade B	A298-62T	E310-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-59
39	A312-62T and A106-62T	316 ELC Welded to Grade B	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-60

Figure 3-21. Detailed Welding Procedure (Sheet 5 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
40	A312-62T and A106-62T	316 ELC Welded to Grade B	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-61
41	A312-62T	316 ELC Welded to Grade B, using consumable insert	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-62
42	A312-62T and A106-62T	316 ELC Welded to Grade B, using consumable insert	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-63
43	A312-62T	347 Welded to 347	A298-62T	E347-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-64
44	A312-62T	347 Welded to 347	A371-62T	ER347	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-65
45	A312-62T	347 Welded to 347	A371-62T and A298-62T	ER347 and E347-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-66
46	A312-62T	347 Welded to 347, using consumable insert	A371-62T	ER347	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-67

Figure 3-21. Detailed Welding Procedure (Sheet 6 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
47	A312-62T	347 Welded to 347, using consumable insert	A371-62T and A298-62T	ER347 and E347-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-68
48	A312-62T and A106-62T	347 Welded to Grade B	A298-62T	E310-15	Manual Metal Arc	Paragraphs 3-144 through 3-207	Figure 3-69
49	A312-62T and	347 Welded to	A371-62T	ER310	Manual Inert -Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-70
50	A312-62T and A106-62T	347 Welded to Grade B	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-71
51	A312-62T and A106-62T	347 Welded to Grade B, using consumable insert	A371-62T	ER310	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-72
52	A312-62T and A106-62T	347 Welded to Grade B, using consumable insert	A371-62T and A298-62T	ER310 and E310-15	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-73
53	B111-61T	70-30 Copper-Nickel Welded to 70-30 Copper Nickel	B259-57T	RCuNi	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-74

Figure 3-21. Detailed Welding Procedure (Sheet 7 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
54	B111-61T	70-30 Copper-Nickel Welded to 70-30 Copper-Nickel	B259-57T and B225-57T	RCuNi and ECuNi	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-75
55	B111-62T	70-30 Copper-Nickel Welded to 70-30 Copper-Nickel using consumable insert	B259-57T	RCuNi	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-76
56	B111-621T	70-30 Copper-Nickel Welded to 70-30 Copper-Nickel using consumable insert	B259-57T and B222-57T	RCuNi and ECuNi	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-77
57	A312-62T and B111-61T	316 Welded to 70-30 Copper-Nickel	B304-56T	ERN62	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-78
58	A312-62T and B111-61T	316 Welded to 70-30 Copper-Nickel	B304-56T and B295-54T	ERN62 and E3N12	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-79

Figure 3-21. Detailed Welding Procedure (Sheet 8 of 12)



SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
59	A312-62T and B111-61T	316 Welded to 70-30 Copper-Nickel using consumable insert	B304-56T	ERN62	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-80
60	A312-62T and B111-61T	316 Welded to 70-30 Copper-Nickel, using consumable insert	B304-56T and B295-54T	ERN62 and E3N12	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241	Figure 3-81
61	B241-55T, GS11A	6061-T6 Welded to 6061-T6	B285-61T	ER4043	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-82
62	B241-55T, M1A	3003 Welded to 3003	B285-61T	ER4043	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-83
63	B241-55T, M1A B241-55T, GS11A	3003 Welded to 6061-T6	B285-61T	ER4043	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241	Figure 3-84
64	36% Nickel Low-expansion Alloy and 36% Nickel Low-expansion Alloy	36% Nickel Low-expansion Alloy Welded to 36% Nickel Low-expansion Alloy	*	*	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241 and 3-272 through 3-301	Figure 3-85

\* Refer to paragraph 3-289

Figure 3-21. Detailed Welding Procedure (Sheet 9 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
65	36% Nickel Low-Expansion Alloy and 36% Nickel Low-expansion Alloy	36% Nickel Low-expansion Alloy Welded to 36% Nickel Low-expansion Alloy	* and B295-54T	* and E4N10	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-272 through 3-301	Figure 3-86
66	36% Nickel Low-expansion Alloy and 36% Nickel Low-expansion Alloy	36% Nickel Low-expansion Alloy Welded to 36% Nickel Low-expansion Alloy with consumable insert	* and B304-56T	* and ERN62	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241 and 3-272 through 3-301	Figure 3-87
67	36% Nickel Low-expansion Alloy and 36% Nickel Low-expansion Alloy	36% Nickel Low-expansion Alloy Welded to 36% Nickel Low-expansion Alloy with consumable insert	B304-56T and B295-54T	ERN62 and E4N10	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-272 through 3-301	Figure 3-88
68	36% Nickel Low-expansion Alloy and A312-62T	36% Nickel Low-expansion Alloy Welded to 304	B304-56T	ERN62	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241 and 3-272 through 3-301	Figure 3-89
69	36% Nickel Low-expansion Alloy and A312-62T	36% Nickel Low-expansion Alloy Welded to 304	B304-56T and B295-54T	ERN62 and E4N10	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-272 through 3-301	Figure 3-90

Figure 3-21. Detailed Welding Procedure (Sheet 10 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
70	36% Nickel Low-expansion Alloy and A312-62T	36% Nickel Low-expansion Alloy Welded to 304 with consumable insert	B304-56T	ERN62	Manual Inert-Gas Shielded Tungsten Arc	Paragraphs 3-208 through 3-241 and 3-272 through 3-201	Figure 3-91
71	36% Nickel Low-expansion Alloy and A312-62T	36% Nickel Low-expansion Alloy Welded to 304 with consumable insert	B304-56T and B295-54T	ERN62 and E4N10	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-272 through 3-301	Figure 3-92
72	A106-62T Nickel-lined	Grade B with 0.015 Nickel Liner Welded to Grade B with 0.015 Nickel Liner	A371-62T and A298-62T	ER310 and E310-16	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-302 through 3-311	Figure 3-93
73	A106-62T Nickel lined	Grade B with 0.015 Nickel Liner Welded to Grade B with 0.015 Nickel Liner with consumable insert	A371-62T and A298-62T	ER310 and E310-16	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-302 through 3-311	Figure 3-94

Figure 3-21. Detailed Welding Procedure (Sheet 11 of 12)

SPECIFICATION NO.	MATERIAL		FILLER METAL		PROCESS	PROCEDURE	CERTIFICATION
	ASTM SPECIFICATION	TYPE	ASTM SPECIFICATION	TYPE			
74	A106-62T Nickel-lined and A312-62T	Grade B with 0.015 Nickel Liner Welded to 316	A371-62T and A298-62T	ER310 and E310-16	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-302 through 3-311	Figure 3-95
75	A106-62T Nickel-lined and A312-62T	Grade B with 0.015 Nickel Liner Welded to 316 with consumable insert	A371-62T and A298-62T	ER310 and E310-16	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	Paragraphs 3-144 through 3-241 and 3-302 through 3-311	Figure 3-96

Figure 3-21. Detailed Welding Procedure (Sheet 12 of 12)

**CERTIFIED PROCEDURE**  
**HORIZONTAL AND VERTICAL PIPE AXIS**

WELDING PROCESS Manual Metal Arc

MATERIAL A106-62T, Grade B (Specification) WELDED TO A106-62T, Grade B

PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall

THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"

FILLER METAL SPECIFICATION A233-58T, E6010

CHEMICAL ANALYSIS 0.30 (max) Carbon Steel

INERT GAS COMPOSITION None FLOW RATE None

TYPE BACKING USED None

PREHEAT TREATMENT None

FILLER ELECTRODE OR WIRE DIAMETER 1/8"

TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp. (P&H) Electrodes

FOREHAND OR BACKHAND TECHNIQUE Forehand

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 60,000 psi

STRESS RELIEVING PROCEDURE None

POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat, Fixed Position	Weld Horizontal, Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-110	85-110
VOLTS	30	30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	18" per hr (4 passes)	12" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	—	44,409	68,390	30	—
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	49,017	74,104	22	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,893	71,344	25	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	42,880	67,785	22	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,632	69,785	22	Weld

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-22. Certified Procedures and Test Data - Specification No. 1

CERTIFIED PROCEDURE HORIZONTAL AND VERTICAL PIPE AXIS	
WELDING PROCESS	Manual Oxy Acetylene
MATERIAL	A106-62T, Grade B (specification) WELDED TO A-106-62T, Grade B
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/8"
FILLER METAL SPECIFICATION	A251-46T, GA60
CHEMICAL ANALYSIS	0.30 (max) Carbon Steel
INERT GAS COMPOSITION	None FLOW RATE None
TYPE BACKING USED	None
PREHEAT TREATMENT	None
FILLER ELECTRODE OR WIRE DIAMETER	1/8"
TRADE NAME ROD USED TO OBTAIN DATA	Page Hi-Test
FOREHAND OR BACKHAND TECHNIQUE	Forehand
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	60,000 psi
STRESS RELIEVING PROCEDURE	None
POSTHEAT TREATMENT	Heat to 300°F, Cool in Still Air

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat, Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (3 Passes)	Multiple (4 passes)
INTERPASS TEMPERATURE	300°F (max)	300°F (max)
AMPERES	-----	-----
VOLTS	-----	-----
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (3 passes)	8" per hr (4 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	---	44,409	68,390	30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	40,000	63,100	24.5	Weld
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	39,150	62,000	24.5	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	40,400	63,200	23.5	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	39,713	66,354	24	Weld

GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Metal Arc  
 MATERIAL A312-62T, Type 304 S.S. (specification) WELDED TO A312-62T, Type 304 S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A298-62T, E308-15  
 CHEMICAL ANALYSIS Chromium 18.0-21.0%, Nickel 9.0-11.0%  
 INERT GAS COMPOSITION None FLOW RATE None  
 TYPE BACKING USED None  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 p.s.i.  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal, Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (7 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-100	70-85
VOLTS	22-28	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	7" per hr (7 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	----	36,327	83,156	42	---
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	44,978	83,214	56	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,172	82,817	56	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	47,756	82,786	59	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	48,791	83,178	60	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-24. Certified Procedures and Test Data - Specification No. 3

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten ArcMATERIAL A312-62T, Type 304 S.S.(specification)WELDED TO A312-62T, Type 304 S.S.PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" WallTHICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"FILLER METAL SPECIFICATION A371-62T, ER308CHEMICAL ANALYSIS Chromium 19.5-22.0%, Nickel 9.0-11.0%INERT GAS COMPOSITION Argon Welding Grade 99.99% PurityFLOW RATE 20 cfhTYPE BACKING USED Argon Gas PurgePREHEAT TREATMENT NoneFILLER ELECTRODE OR WIRE DIAMETER First pass 3/22", subsequent passes 1/8"TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp bare rodFOREHAND OR BACKHAND TECHNIQUE ForehandNORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psiSTRESS RELIEVING PROCEDURE NonePOSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, Flat, Fixed Position	Weld Horizontal, Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (7 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-105	70-100
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	9" per hr (7 passes)	9" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	---	36,327	83,156	42	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	44,943	82,821	55	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,396	82,893	51	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	39,339	80,660	58	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	41,284	83,543	66	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-25. Certified Procedures and Test Data - Specification No. 4



CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc (1st pass) Manual Metal Arc (subsequent passes)	
MATERIAL	A312-62T, Type 304 S. S. (specification)	WELDED TO A312-62T, Type 304 S. S.
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A37-62T, ER308, and A298-62T, E308-15	
CHEMICAL ANALYSIS	Chromium 18.0-21.0% - Nickel 9.0-11.0%	
INERT GAS COMPOSITION	Argon Welding Grade, 99.99%	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First pass 3/32", subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Bare Rod, Harnischfeger Covered Electrode	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-115	70-110
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	---	36,327	83,156	42	----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	42,700	81,642	51	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	46,214	81,200	46	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,402	86,034	66	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	42,361	82,570	57	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-26. Certified Procedures and Test Data - Specification No. 5

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 304 (specification) **WELDED TO** A312-62T, Type 304  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, EB 308  
**CHEMICAL ANALYSIS** Chromium 19.5-22%, Nickel 9.0-11.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal, Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (7 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
<b>AMPERES</b>	80-120	75-115
<b>VOLTS</b>	24-26	26-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (7 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	---	36,321	83,156	42	----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	40,558	82,588	58	Weld
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	42,230	83,530	57	Weld
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	40,606	79,393	41	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,650	76,300	46.5	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-27. Certified Procedures and Test Data - Specification No. 6

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc (first Pass) Manual Metal Arc (subsequent passes)	
MATERIAL	A312-62T, Type 304 S.S. (specification)	WELDED TO A312-62T, Type 304 SS.
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375 Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A371-62T, ER 308 and A298-62T, E 308-15	
CHEMICAL ANALYSIS	Chromium 18.0-21.0%, Nickel 9.0-11.0%	
INERT GAS COMPOSITION	Argon Welding Grade, 99.99% purity	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First pass 3/32", subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. EB Insert, Harnischfeger Corp. Covered Electrodes	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal ; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (3 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	75-115	70-115
VOLTS	26-28	26-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (3 passes)	9" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	---	36,327	83,156	42	----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	42,871	81,456	54	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,396	81,184	53	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	42,501	81,331	48	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	42,487	80,452	52	Weld

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-28. Certified Procedures and Test Data - Specification No. 7

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc

MATERIAL A312-62T, Type 304 S. S.(specification) WELDED TO A106-62T, Grade B

PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall

THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"

FILLER METAL SPECIFICATION A298-62T, E310-15

CHEMICAL ANALYSIS Chromium 25.0-28.0% Nickel 20.0-22.5%

INERT GAS COMPOSITION None FLOW RATE None

TYPE BACKING USED None

PREHEAT TREATMENT None

FILLER ELECTRODE OR WIRE DIAMETER 1/8"

TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp (P&H) Electrodes

FOREHAND OR BACKHAND TECHNIQUE Forehand

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi

STRESS RELIEVING PROCEDURE None

POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	75-85	70-85
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	7" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304 Grade B</u>	-----	<u>36,327</u> <u>44,409</u>	<u>83,156</u> <u>68,390</u>	<u>42</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	50,000	70,040	22	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	48,287	72,801	26	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	48,720	69,976	30	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,530	68,531	30	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-29. Certified Procedures and Test Data - Specification No. 8

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc	
MATERIAL	A312-62T, Type 304 S. S.(specification)	WELDED TO A106-62T, Grade B
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A371-62T, ER310	
CHEMICAL ANALYSIS	Chromium 25.0-28.0%, Nickel 20.0-22.5%	
INERT GAS COMPOSITION	Argon Welding Grade, 99.99% Purity	FLOW RATE 15-20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First three passes 3/22", subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp.	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (7 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	80-115	70-115
VOLTS	26-30	26-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	8" per hr (8 passes)	7" per hr (7 passes)

TEST DATA REDUCED SECTION TENSILE TEST					
DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <sup>304</sup> Grade B	-----	36,327 44,409	83,156 68,390	42 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	43,150	70,360	26	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	44,371	70,900	27	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	43,670	74,205	27	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	45,955	70,900	26	P. M. C. S.

GUIDED BEND TEST - WELD COUPON				
DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-30. Certified Procedures and Test Data - Specification No.9

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 304 S. S. (specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 15-20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/22", Subsequent passes 5/32"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (3 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	75-115	70-120
VOLTS	26-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (3 passes)	9" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304 Grade B</u>	-----	<u>36,327</u> <u>44,409</u>	<u>83,156</u> <u>68,390</u>	<sup>42</sup> 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	44,023	71,207	28	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,743	72,256	27	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,818	69,818	28	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,760	71,460	26	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-31. Certified Procedures and Test Data - Specification No. 10

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL A312-62T, Type 304 S. S.(specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	75-115	70-110
VOLTS	24-28	24-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304 Grade B</u>	-----	<u>36,327</u> <u>44,409</u>	<u>83,156</u> <u>68,390</u>	<u>42</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	44,074	71,851	28	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,750	72,500	28	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,942	71,220	26	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,783	70,410	26	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-32. Certified Procedures and Test Data - Specification No.11

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass), Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 304 S.S.(specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER308 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. EB Inert Harnischfeger (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (7 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	75-115	80-120
VOLTS	28-30	23-26
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (7 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304 Grade B</u>	-----	<u>36,327</u> <u>44,409</u>	<u>83,156</u> <u>68,390</u>	<u>42</u> <u>30</u>	----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	48,882	74,516	28	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,431	67,237	23	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	44,475	68,839	26	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	46,247	68,418	26	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-33. Certified Procedures and Test Data - Specification No.12



**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Metal Arc  
**MATERIAL** A312-62T, Type 304 ELC S.S.(specification) **WELDED TO** A312-62T, Type 304ELC S.S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A298-62T, E308L-15  
**CHEMICAL ANALYSIS** Chromium 18.0-21%, Nickel 9.0-11.0%  
**INERT GAS COMPOSITION** None **FLOW RATE** None  
**TYPE BACKING USED** None  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Harnischfeger (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 75,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F(max)
<b>AMPERES</b>	70-85	75-90
<b>VOLTS</b>	22-28	22-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (4 passes)	7" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	31,016	76,986	41	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	42,498	77,474	56	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	39,850	77,197	57	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	42,387	78,662	64	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	39,451	77,082	64	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-34. Certified Procedures and Test Data - Specification No.13

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL A312-62T, Type 304 ELC S.S.(specification) WELDED TO A312-62T, Type 304 ELC S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER308L  
 CHEMICAL ANALYSIS Chromium 19.5-22.0%, Nickel 9.0-11.0%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 75,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	85-105	85-115
VOLTS	24-28	24-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	31,016	76,986	41	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	39,870	76,630	56	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	40,000	76,850	54	Weld
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	39,870	75,320	41	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,570	77,190	49	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-35. Certified Procedures and Test Data - Specification No.14

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	
MATERIAL	A312-62T, Type 304 ELC S. S. (specification) WELDED TO A312-62T, Type 304 ELC S. S.	
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A371-62T, ER308L and A298-62T E308L-15	
CHEMICAL ANALYSIS	Chromium 18.0-21.0%, Nickel 9.0-11.0%	
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First pass 3/32", Subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Bare Rods Harnischfeger Corp (P&H) Electrodes	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	75,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-115	70-110
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	31,016	76,986	41	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	38,603	77,363	62	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	39,081	77,490	57	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	37,726	77,201	58	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	42,120	77,428	53	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-36. Certified Procedures and Test Data - Specification No. 15

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL A312-62T, Type 304 ELC S.S.(specification) WELDED TO A312-62T, Type 304 ELC S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER308L  
 CHEMICAL ANALYSIS Chromium 19.5-22.0%, Nickel 9.0-11.0%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 15-20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 75,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	75-105	75-115
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	31,016	76,986	41	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	42,830	76,920	49	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	44,243	78,581	62	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	35,160	76,890	56	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	36,520	75,590	54	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-37. Certified Procedures and Test Data - Specification No. 16

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc Manual Metal Arc (subsequent passes)	
MATERIAL	A312-62T, Type 304 ELC S. S. (specification) WELDED TO A312-62T, Type 304 ELC S. S.	
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A371-62T, ER308L, and A298-62T, E308L-15	
CHEMICAL ANALYSIS	Chromium 18.0-21.0%, Nickel 9.0-11.0%	
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First Pass 3/32", Subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp., EB Inert Harnischfeger Corp (P&H) Electrodes	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	75,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-115	70-110
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA					
REDUCED SECTION TENSILE TEST					
DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	31,016	76,986	41	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	38,994	77,988	64	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	39,591	77,871	62	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	38,497	76,145	63	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	35,926	76,897	68	P. M.

GUIDED BEND TEST - WELD COUPON				
DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-38. Certified Procedures and Test Data - Specification No.17

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Metal Arc  
**MATERIAL** A312-62T, Type 304 ELC S. S. (specification) **WELDED TO** A106-62 Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A298-62T, E310-15  
**CHEMICAL ANALYSIS** Chromium 25.0-28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** None **FLOW RATE** None  
**TYPE BACKING USED** None  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Harnischfeger Corp (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	70-85	75-90
<b>VOLTS</b>	25-30	25-30
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304L Grade B</u>	-----	31,016 44,409	76,986 68,390	41 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	42,680	70,322	26	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	39,455	70-596	26	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	40,000	67,981	29	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,575	71,455	28	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-39. Certified Procedures and Test Data - Specification No. 18

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL A312-62T, Type 304 ELC S. S.(specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig.3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	75-115	75-115
VOLTS	24-28	24-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304 L Grade B</u>	-----	<u>31,016</u> <u>44,409</u>	<u>76,986</u> <u>68,390</u>	<u>41</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	47,106	69,733	29	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,840	70,720	27	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	43,220	70,030	28	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,180	69,680	28	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-40. Certified Procedures and Test Data - Specification No. 19

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 304 ELC S.S.(specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-115	70-110
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304 L Grade B</u>	-----	<u>31,016</u> <u>44,409</u>	<u>76,986</u> <u>68,390</u>	<u>41</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	43,869	69,291	22	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,810	68,376	22	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,509	69,733	26	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,730	68,489	26	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-41. Certified Procedures and Test Data - Specification No.20



**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 304 ELC S. S.(specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER310  
**CHEMICAL ANALYSIS** Chromium 25.0-28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rod  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
<b>AMPERES</b>	70-105	70-105
<b>VOLTS</b>	24-28	24-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304L Grade B</u>	-----	<u>31,016</u> <u>44,409</u>	<u>76,986</u> <u>68,390</u>	<u>41</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	41,164	70,636	27	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,289	68,674	26	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	43,962	67,121	28	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	45,592	69,119	28	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-42. Certified Procedures and Test Data - Specification No. 21

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** A312-62T, Type 304 ELC S.S.(specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER310 and A298-62T, E310-15  
**CHEMICAL ANALYSIS** Chromium 25.0-28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. EB Inert Harnischfeger Corp. (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-115	70-115
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>304L Grade B</u>	-----	31,016 44,409	76,986 68,390	41 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	42,276	67,154	30	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	41,919	69,112	27	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	40,598	68,626	41	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	47,619	70,135	41	P. M. C. S.

GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-43. Certified Procedures and Test Data - Specification No. 22

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc  
 MATERIAL A312-62T, Type 316 S.S.(specification) WELDED TO A312-62T, Type 316 S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A298-62T, E316-15  
 CHEMICAL ANALYSIS Chromium 17.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-2.5%  
 INERT GAS COMPOSITION None FLOW RATE None  
 TYPE BACKING USED None  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-90	70-85
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	35,707	75,415	40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	46,296	76,931	68	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	49,468	75,942	48	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	43,712	76,927	46	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,458	75,619	54	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-44. Certified Procedures and Test Data - Specification No. 23

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 316 S.S.(specification) **WELDED TO** A312-62T, Type 316 S.S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER 316  
**CHEMICAL ANALYSIS** Chromium 18.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-3.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rod  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	70-105	70-105
<b>VOLTS</b>	24-28	26-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	35,707	75,415	40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	43,020	76,530	49	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	41,035	76,073	60	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,928	77,701	62	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	49,105	82,665	48	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-45. Certified Procedures and Test Data - Specification No. 24

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 316 S.S.(specification) WELDED TO A312-62T, Type 316 S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER316 and A298-62T, E316-15  
 CHEMICAL ANALYSIS Chromium 17.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-2.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods Harnischfeger (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	85-120	85-120
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	35,707	75,415	40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	45,360	76,460	55	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	42,830	71,320	49	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	40,560	75,460	54	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	41,750	75,260	50	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-46. Certified Procedures and Test Data - Specification No. 25

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 316 S.S.(specification) **WELDED TO** A312-62T, Type 316 S.S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER316  
**CHEMICAL ANALYSIS** Chromium 18.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-3.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
<b>AMPERES</b>	70-105	70-105
<b>VOLTS</b>	24-28	24-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	35,707	75,415	40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	41,191	75,951	56	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	41,860	75,923	58	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	50,773	77,256	60	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,511	77,234	56	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-47. Certified Procedures and Test Data - Specification No. 26

CERTIFIED PROCEDURE		
WELDING PROCESS <u>Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)</u>		
MATERIAL <u>A312-62T, Type 316 S.S.(specification)</u> WELDED TO <u>A312-62T, Type 316 S.S.</u>		
PIPE SIZE AND WALL THICKNESS <u>5" Schedule 80, 0.375" Wall</u>		
THICKNESS RANGE THIS TEST QUALIFIES <u>3/16" through 3/4"</u>		
FILLER METAL SPECIFICATION <u>A371-62T, ER316 and A298-62T, E316-15</u>		
CHEMICAL ANALYSIS <u>Chromium 17.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-2.5%</u>		
INERT GAS COMPOSITION <u>Argon Welding Grade 99.99% Purity</u> FLOW RATE <u>20 cfh</u>		
TYPE BACKING USED <u>Argon Gas Purge</u>		
PREHEAT TREATMENT <u>None</u>		
FILLER ELECTRODE OR WIRE DIAMETER <u>First pass 3/32", Subsequent passes 1/8"</u>		
TRADE NAME ROD USED TO OBTAIN DATA <u>Arcos Corp. EB Insert Harnischfeger Corp (P&amp;H) Electrodes</u>		
FOREHAND OR BACKHAND TECHNIQUE <u>Forehand</u>		
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION <u>80,000 psi</u>		
STRESS RELIEVING PROCEDURE <u>None</u>		
POSTHEAT TREATMENT <u>None</u>		

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	85-120	85-120
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	35,707	75,415	40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	45,064	77,146	59	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	46,753	76,210	56	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	42,497	76,259	60	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	46,915	76,649	60	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-48. Certified Procedures and Test Data - Specification No. 27

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc

MATERIAL A312-62T, Type 316 S. S. (specification) WELDED TO A106-62T, Grade B

PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall

THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"

FILLER METAL SPECIFICATION A298-62T, E310-15

CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%

INERT GAS COMPOSITION None FLOW RATE None

TYPE BACKING USED None

PREHEAT TREATMENT None

FILLER ELECTRODE OR WIRE DIAMETER 1/8"

TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp (P&H) Electrodes

FOREHAND OR BACKHAND TECHNIQUE Forehand

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi

STRESS RELIEVING PROCEDURE None

POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	75-120	75-120
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	10" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>316 Grade B</u>	-----	<u>35,707</u> <u>44,409</u>	<u>75,415</u> <u>68,390</u>	<u>40</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	41,790	70,420	25	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,550	71,130	28	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	41,236	70,210	26	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	46,250	68,975	26	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-49. Certified Procedures and Test Data - Specification No. 28



CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc	
MATERIAL	A312-62T, Type 316 S. S. (specification)	WELDED TO A106-62T, Grade B
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A371-62T, ER310	
CHEMICAL ANALYSIS	Chromium 25.0-28.0%, Nickel 20.0-22.5%	
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First pass 3/32", Subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Bare Rods	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-105	70-105
VOLTS	24-28	24-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <sup>316</sup> Grade B	-----	35,707 44,409	75,415 68,390	40 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	45,524	67,559	23	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	46,406	69,574	25	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	41,991	65,801	28	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2	40,248	66,034	25	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-50. Certified Procedures and Test Data - Specification No.29

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 316 (specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310; A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-100	70-100
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	11" per hr (4 passes)	9" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>316 Grade B</u>	-----	<u>35,707</u> <u>44,409</u>	<u>75,415</u> <u>68,390</u>	<u>40</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	47,500	71,400	26	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,850	70,400	27	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	44,000	67,600	29	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,500	67,350	27	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-51. Certified Procedures and Test Data - Specification No. 30

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc	
MATERIAL	A312-62T, Type 316 S. S. (specification)	WELDED TO A106-62T Grade B
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A371-62T, ER310	
CHEMICAL ANALYSIS	Chromium 25.0 to 28.0%, Nickel 20.0-22.5%	
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	First pass 3/32" Subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Bare Rod	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-105	70-105
VOLTS	24-28	24-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <sup>316</sup> Grade B	-----	35,707 44,409	75,415 68,390	40 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	41,621	66,277	23	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	40,858	67,962	28	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	46,179	68,833	25	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,043	69,202	27	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	-----	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	-----	-----
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-52. Certified Procedures and Test Data - Specification No. 31

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 316 S. S. (specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. EB Insert Harnischfeger Corp. (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	85-120	85-120
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <sup>316</sup> Grade B	-----	35,707 44,409	75,415 68,390	40 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	44,827	68,501	26	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,705	70,475	26	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	42,362	67,950	25	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,157	68,367	27	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-53. Certified Procedures and Test Data - Specification No. 32

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Metal Arc	
MATERIAL	A312-62T, Type 316 ELC S. S. (specification) WELDED TO A312-62T, Type 316 ELC S. S.	
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	A298-62T, E316L-15	
CHEMICAL ANALYSIS	Chromium 17.0-20%, Nickel 11.0-14.0%, Moly 2.0-2.5%	
INERT GAS COMPOSITION	None	FLOW RATE None
TYPE BACKING USED	None	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Harnischfeger (P&H) Electrodes	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	75,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (6 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-80	70-85
VOLTS	22-28	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (6 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	27,088	74,478	43	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	43,226	76,396	50	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	44,399	76,476	52	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	51,425	76,353	44	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	47,727	78,484	56	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-54. Certified Procedures and Test Data - Specification No.33

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 304 ELC S.S.(specification) **WELDED TO** A312-62T, Type 304 ELC S.S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER316L  
**CHEMICAL ANALYSIS** Chromium 18.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-3.0%  
**INERT GAS COMPOSITION** Argon Welding Grade, 99.99% Purity **FLOW RATE** 20.cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent Passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 75,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (6 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	80-115	85-120
<b>VOLTS</b>	26-30	26-30
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	11" per hr (6 passes)	9" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	27,088	74,478	43	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	47,122	74,758	48	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	42,791	70,022	44	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	46,104	76,220	52	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,200	76,790	54	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-55. Certified Procedures and Test Data - Specification No.34

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 316 ELC S.S.(specification) WELDED TO A312-62T, Type 316 ELC S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER316L and A298-62T, E316L-15  
 CHEMICAL ANALYSIS Chromium 17.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-2.5%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 75,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-115	70-110
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	27,088	74,478	43	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	46,643	74,441	44	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	44,009	76,120	40	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	48,560	80,155	53	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,359	77,298	64	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-56. Certified Procedures and Test Data - Specification No.35

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL A312-62T, Type 316 ELC S.S.(specification) WELDED TO A312-62T, Type 316 ELC S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER316L  
 CHEMICAL ANALYSIS Chromium 18.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-3.0%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 75,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (7 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-120	75-120
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (7 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	27,088	74,478	43	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	50,901	75,198	50	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,132	75,805	62	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	48,893	71,222	37	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	45,240	76,615	58	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-57. Certified Procedures and Test Data - Specification No.36



## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** A312-62T, Type 316 ELC S.S.(specification) **WELDED TO** A312-62T, Type 316 ELC S.S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER316L and A298-62T, E316L-15  
**CHEMICAL ANALYSIS** Chromium 17.0-20.0%, Nickel 11.0-14.0%, Moly 2.0-2.5%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First Pass 3/32", Subsequent Passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. EB Insert Harnischfeger Corp (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 75,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
<b>AMPERES</b>	70-115	70-110
<b>VOLTS</b>	28-30	28-30
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	27,088	74,478	43	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	49,142	77,333	42	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,779	72,876	40	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	41,705	73,161	59	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	45,498	73,946	60	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-58. Certified Procedures and Test Data - Specification No.37

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Metal Arc  
 MATERIAL A312-62T, Type 316 ELC S.S.(specification) WELDED TO A106-62T Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION None FLOW RATE None  
 TYPE BACKING USED None  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-85	70-85
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>316L Grade B</u>	-----	27,088 44,409	74,478 68,390	43 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	55,121	71,498	22	P.M. C.S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	49,622	69,788	22	P.M. C.S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	46,019	68,796	22	P.M. C.S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	46,095	67,732	23	P.M. C.S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-59. Certified Procedures and Test Data - Specification No. 38

CERTIFIED PROCEDURE		
WELDING PROCESS <u>Manual Inert-Gas Shielded Tungsten Arc</u>		
MATERIAL <u>A312-62T, Type 316 ELC S.S.(specification)</u>		WELDED TO <u>A106-62T, Grade B</u>
PIPE SIZE AND WALL THICKNESS <u>5" Schedule 80, 0.375" Wall</u>		
THICKNESS RANGE THIS TEST QUALIFIES <u>3/16" through 3/4"</u>		
FILLER METAL SPECIFICATION <u>A371-62T, ER 310</u>		
CHEMICAL ANALYSIS <u>Chromium 25.0-28.0%, Nickel 20.0-22.5%</u>		
INERT GAS COMPOSITION <u>Argon Welding Grade 99.99% Purity</u>		FLOW RATE <u>20 cfh</u>
TYPE BACKING USED <u>Argon Gas Purge</u>		
PREHEAT TREATMENT <u>None</u>		
FILLER ELECTRODE OR WIRE DIAMETER <u>First pass 3/32", Subsequent passes 1/8"</u>		
TRADE NAME ROD USED TO OBTAIN DATA <u>Arcos Corp. Bare Rods</u>		
FOREHAND OR BACKHAND TECHNIQUE <u>Forehand</u>		
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION <u>80,000 psi</u>		
STRESS RELIEVING PROCEDURE <u>None</u>		
POSTHEAT TREATMENT <u>None</u>		

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (6 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	80-120	75-120
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (6 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <span style="float: right;">316L Grade B</span>	-----	27,088 44,409	74,478 68,390	<sup>43</sup> 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	51,419	68,013	22	P.M. C.S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	48,000	69,071	24	P.M. C.S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	46,809	69,732	24	P.M. C.S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	47,322	70,174	28	P.M. C.S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-60. Certified Procedures and Test Data - Specification No. 39

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 316 ELC S.S.(specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp, Bare Rods Harnischfeger Corp (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-115	70-115
VOLTS	26-28	26-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	10" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>316L Grade B</u>	-----	<u>27,088</u> <u>44,409</u>	<u>74,478</u> <u>68,390</u>	<u>43</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	44,643	69,246	28	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	50,544	68,367	26	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	47,145	69,685	32	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	48,036	69,486	33	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-61. Certified Procedures and Test Data - Specification No. 40

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 316 ELC S.S.(specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER310  
**CHEMICAL ANALYSIS** Chromium 25.0-28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** \_\_\_\_\_

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	75-115	70-115
<b>VOLTS</b>	26-28	26-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>316L Grade B</u>	-----	<u>27,088</u> <u>44,409</u>	<u>74,478</u> <u>68,390</u>	<u>43</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	41,559	68,441	28	P.M. C.S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	44,341	65,943	25	P.M. C.S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,290	70,990	28	P.M. C.S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	44,540	70,880	28	P.M. C.S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-62. Certified Procedures and Test Data - Specification No. 41

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 316 ELC S.S.(specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. EB Insert Harnischfeger Corp. (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-85	70-85
VOLTS	25-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>316L Grade B</u>	-----	<u>27,088</u> <u>44,408</u>	<u>74,478</u> <u>68,390</u>	<u>43</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	45,100	70,650	29	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,924	68,886	28	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	46,250	70,190	29	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,700	71,050	29	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-63. Certified Procedures and Test Data - Specification No. 42

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc  
 MATERIAL A312-62T, Type 347 S.S.(specification) WELDED TO A312-62T, Type 347 S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A298-62T, E347-15  
 CHEMICAL ANALYSIS Chromium 18.0-21.0%, Nickel 9.0-11.0%  
 INERT GAS COMPOSITION None FLOW RATE None  
 TYPE BACKING USED None  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Harnischfeger Corp. (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (7 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-85	70-85
VOLTS	22-28	22-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	10" per hr (7 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	38,196	86,878	44	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	53,744	85,903	45	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	55,524	86,993	40	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	53,508	90,620	50	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	50,734	89,720	50	P.M.

GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-64. Certified Procedures and Test Data - Specification No. 43

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL A312-62T, Type 347 S.S.(specification) WELDED TO A312-62T, Type 347 S.S.  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER347  
 CHEMICAL ANALYSIS Chromium 19.0-21.5%, Nickel 9.0-11.0%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-105	70-105
VOLTS	24-28	24-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (8 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	38,196	86,878	44	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	53,794	86,215	44	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,912	86,859	52	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	50,101	88,555	54	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	54,925	96,537	51	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-65. Certified Procedures and Test Data - Specification No. 44



**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** A312-62T, Type 347 S.S.(specification) **WELDED TO** A312-62T, Type 347 S.S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER347 and A298-62T, E347-15  
**CHEMICAL ANALYSIS** Chromium 18.0-21.0%, Nickel 9.0-11.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods Harnischfeger Corp. (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	70-85	70-85
<b>VOLTS</b>	25-	25-30
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	38,196	86,878	44	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	50,103	88,278	48	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	55,961	87,514	44	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	52,802	85,415	42	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	48,211	87,232	63	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-66. Certified Procedures and Test Data - Specification No. 45

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 347 S. S. (specification) **WELDED TO** A312-62T, Type 347 S. S.  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER347  
**CHEMICAL ANALYSIS** Chromium 19.0-21.5%, Nickel 9.0-11.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32" Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	70-105	70-105
<b>VOLTS</b>	24-28	24-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	38,196	86,878	44	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	47,222	83,838	46	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	49,713	85,893	50	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,539	86,176	50	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	50,165	91,639	43	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-67. Certified Procedures and Test Data - Specification No. 46

CERTIFIED PROCEDURE		
WELDING PROCESS <u>Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)</u>		
MATERIAL <u>A312-62T, Type 347 S.S.(specification)</u> WELDED TO <u>A312-62T, Type 347 S.S.</u>		
PIPE SIZE AND WALL THICKNESS <u>5" Schedule 80, 0.375" Wall</u>		
THICKNESS RANGE THIS TEST QUALIFIES <u>3/16" through 3/4"</u>		
FILLER METAL SPECIFICATION <u>A371-62T, ER347 and A298-62T, E347-15</u>		
CHEMICAL ANALYSIS <u>Chromium 18.0-21.0%, Nickel 9.0-11.0%</u>		
INERT GAS COMPOSITION <u>Argon Welding Grade 99.99% Purity</u> FLOW RATE <u>20 cfh</u>		
TYPE BACKING USED <u>Argon Gas Purge</u>		
PREHEAT TREATMENT <u>None</u>		
FILLER ELECTRODE OR WIRE DIAMETER <u>First pass 3/32", Subsequent passes 1/8"</u>		
TRADE NAME ROD USED TO OBTAIN DATA <u>Arcos Corp. EB Inserts Harnischfeger Corp. (P&amp;H) Electrodes</u>		
FOREHAND OR BACKHAND TECHNIQUE <u>Forehand</u>		
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION <u>80,000 psi</u>		
STRESS RELIEVING PROCEDURE <u>None</u>		
POSTHEAT TREATMENT <u>None</u>		

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-85	70-85
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	38,196	86,878	44	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	51,709	89,248	54	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	56,332	78,034	42	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	50,333	87,432	50	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	50,669	88,293	48	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-68. Certified Procedures and Test Data - Specification No. 47

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Metal Arc  
**MATERIAL** A312-62T, Type 347 S. S.(specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A298-62T, E310-15  
**CHEMICAL ANALYSIS** Chromium 25.0 to 28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** None **FLOW RATE** None  
**TYPE BACKING USED** None  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Harnischfeger Corp. (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	95-120	95-120
<b>VOLTS</b>	28-30	28-30
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>347 Grade B</u>	-----	38,196 44,409	86,878 68,390	44 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	43,828	77,650	22	P.M. C.S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	43,825	71,420	25	P.M. C.S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	43,810	70,050	29	P.M. C.S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	41,710	69,740	28	P.M. C.S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-69. Certified Procedures and Test Data - Specification No. 48

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 347 (specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4  
**FILLER METAL SPECIFICATION** A371-62T, ER310  
**CHEMICAL ANALYSIS** Chromium 25.0-28%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** Argon Welding Grade, 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-2
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	75-110	75-110
<b>VOLTS</b>	24-28	24-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <sup>347</sup> Grade B	-----	38,196 44,409	86,878 88,390	44 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	41,400	66,400	24	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	43,150	65,100	29	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	44,350	66,900	26	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	41,900	65,200	22.5	P. M. C. S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-70. Certified Procedures and Test Data - Specification No. 49

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (Subsequent passes)  
**MATERIAL** A312-62T, Type 347 S.S.(specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER310, and A298-62T, E310-15  
**CHEMICAL ANALYSIS** Chromium 25.0-28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** Argon Welding Grade, 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods. Harnischfeger Corp. (P&H) Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300 <sup>o</sup> F (max)	300 <sup>o</sup> F (max)
AMPERES	70-85	70-85
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>Grade 347</u>	-----	<u>38,196</u> <u>44,409</u>	<u>86,878</u> <u>88,390</u>	<u>24</u> <u>22</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	47,668	70,066	24	P.M. C.S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	47,327	70,328	22	P.M. C.S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	45,029	69,006	25	P.M. C.S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,207	69,674	26	P.M. C.S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-71. Certified Procedures and Test Data - Specification No.50

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** A312-62T, Type 347 S. S. (specification) **WELDED TO** A106-62T, Grade B  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER310  
**CHEMICAL ANALYSIS** Chromium 25.0-28.0%, Nickel 20.0-22.5%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 3/32", Subsequent passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	75-105	75-115
<b>VOLTS</b>	24-28	26-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (8 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>347 Grade B</u>	-----	38,196 44,409	86,878 88,390	44 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	45,460	70,470	24	P.M. C.S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	42,420	69,560	23	P.M. C.S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	44,020	71,350	24	P.M. C.S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,720	70,990	22	P.M. C.S.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-72. Certified Procedures and Test Data - Specification No.51

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A312-62T, Type 347 S. S. (specification) WELDED TO A106-62T, Grade B  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-15  
 CHEMICAL ANALYSIS Chromium 25.0-28.0%, Nickel 20.0-22.5%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. EB Insert Harnischfeger Corp. (P&H) Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	70-85	70-85
VOLTS	25-30	25-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	12" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>347 Grade B</u>	-----	<u>38,196</u> <u>44,409</u>	<u>86,878</u> <u>68,390</u>	<u>44</u> <u>30</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	46,780	70,352	23	P. M. C. S.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	45,198	69,027	22	P. M. C. S.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	39,435	68,948	28	P. M. C. S.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	43,646	69,208	25	P. M. C. S.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-73. Certified Procedures and Test Data - Specification No.52



**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc

MATERIAL B111-61T, 70-30 Cu Ni (specification) WELDED TO B111-61T, 70-30 Cu Ni

PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" Wall

THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"

FILLER METAL SPECIFICATION B259-57T, R Cu Ni

CHEMICAL ANALYSIS Copper 67.0-70.0%, Nickel 29.0-33.0%

INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh

TYPE BACKING USED Argon Gas Purge

PREHEAT TREATMENT Preheat to 350° F. : Maintain preheat temperature throughout Welding Operation; Cool in Still Air.

FILLER ELECTRODE OR WIRE DIAMETER 1/8"

TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods

FOREHAND OR BACKHAND TECHNIQUE Forehand

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 50,000 psi

STRESS RELIEVING PROCEDURE None

POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	350° F (max)	350° F (max)
AMPERES	130-150	130-150
VOLTS	20-25	20-25
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	9" per hr (8 passes)	7" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	24,073	54,022	30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	26,441	53,677	32	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	27,546	54,240	30	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	32,225	54,385	27	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2	30,730	53,652	28	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-74. Certified Procedures and Test Data - Specification No.53

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL B111-61T, 70-30 Cu Ni (specification) WELDED TO B111-61T, 70-30 Cu Ni  
 PIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375"  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION B259-57T, R Cu Ni and R225-57T, E Cu Ni  
 CHEMICAL ANALYSIS Copper 67.0-70.0%, Nickel 29.0-33.0%  
 INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT Preheat to 350° F.; Maintain preheat Temperature Throughout Welding Operation; Cool in Still Air.  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods and Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 50,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	350° F (max)	350° F (max)
AMPERES	130-150	130-160
VOLTS	28-32	28-32
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	24,073	54,022	30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	39,535	55,116	26	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	36,666	52,844	28	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	33,267	52,349	30	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	30,456	53,443	30	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-75. Certified Procedures and Test Data - Specification No.54

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** B111-61T, 70-30 Cu Ni (specification) **WELDED TO** B111-61T, 70-30 Cu Ni  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** B259-57T, R Cu Ni  
**CHEMICAL ANALYSIS** Copper 67.0-70.0%, Nickel 29.0-33.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** Preheat to 350° F.; Maintain Preheat Temperature throughout Welding Operation; Cool in Still Air.  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 50,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	350° F (max)	350° F (max)
AMPERES	140-150	145-160
VOLTS	38-42	40-42
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	8" per hr (8 passes)	6" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	24,073	54,022	30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	26,848	51,878	28	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	27,033	52,018	30	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	32,225	54,385	27	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	30,730	53,652	27	Weld

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-76. Certified Procedures and Test Data - Specification No. 55

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** B111-61T, 70-30 Cu Ni (specification) **WELDED TO** B111-61T, 70-30 Cu Ni  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** B259-57T, R Cu Ni, B225-57T, E Cu Ni  
**CHEMICAL ANALYSIS** Copper 67.0-70.0%, Nickel 29.0-33.0%  
**INERT GAS COMPOSITION** Argon Welding Grade, 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
 Preheat to 350° F; Maintain Preheat Temperature throughout Welding  
**PREHEAT TREATMENT** Operation; Cool in Still Air.  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rods and Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 50,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-5	See Fig 3-6
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	350° F (max)	350° F (max)
<b>AMPERES</b>	130-150	130-150
<b>VOLTS</b>	28-32	28-32
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	24,073	54,022	30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	27,272	55,002	31	Weld
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	28,732	54,873	39	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	25,294	53,994	33	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	26,549	52,892	29	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-77. Certified Procedures and Test Data - Specification No.56

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc	
MATERIAL	A312-62T, Type 316 S.S.(specification)	WELDED TO B111-61T, 70-30 Cu Ni
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	B304-56T, ERN 62	
CHEMICAL ANALYSIS	Chromium 14.0-17.0%, Nickel 67.0-70.0%	
INERT GAS COMPOSITION	Argon Welding Grade, 99.99% Purity	FLOW RATE 15-20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	Preheat to 350° F; Maintain Preheat Temperature Throughout Welding Operation; Cool in Still Air	
FILLER ELECTRODE OR WIRE DIAMETER	1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Inconel No. 92 Bare Rods	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-1	See Fig 3-2
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (5 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	350° F (max)	350° F (max)
AMPERES	135-145	135-150
VOLTS	36-42	36-42
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	8" per hr (5 passes)	7" per hr (8 passes)

**TEST DATA**  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) Cu Ni 70-30 316	-----	24,073 35,707	54,022 75,415	30 40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	28,843	53,815	26	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	33,651	53,570	24	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	30,323	54,911	27	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	32,213	55,330	26	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-78. Certified Procedures and Test Data - Specification No.57

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** A312-62T, Type 316 S.S.(specification) **WELDED TO** B111-61T, 70-30 Cu Ni  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** B304-56T, ERN62 and B295-54T E3N12  
**CHEMICAL ANALYSIS** Chromium 14.0-17.0%, Nickel 67.0-70.0%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfm  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** Preheat to 350°F; Maintain Preheat Temperature Throughout Welding Operation; Cool in Still Air.  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Inconel No. 92 Bare Rods and Incoweld "A" Electrodes  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-1	See Fig 3-1
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	350° F (max)	350° F (max)
<b>AMPERES</b>	First pass 140-150 Subsequent passes 90-130	First pass 140-150 Subsequent passes 90-130
<b>VOLTS</b>	28-30	28-30
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (4 passes)	8" per hr (8 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>Cu Ni 70-30 316</u>	-----	<del>24,073</del> <del>35,707</del>	<del>54,022</del> <del>75,415</del>	30 40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	32,522	55,365	25	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	34,106	55,585	26	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	31,208	56,098	29	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	31,526	55,097	28	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-79. Certified Procedures and Test Data - Specification No, 58

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc	
MATERIAL	A312-62T, Type 316 S. S. (specification)	WELDED TO B111-61T, 70-30 Cu Ni
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/4"	
FILLER METAL SPECIFICATION	B304-56T, ERN 62	
CHEMICAL ANALYSIS	Chromium 14.0-17.0%, Nickel 67.0-70.0%	
INERT GAS COMPOSITION	Argon Welding Grade, 99.99% Purity	FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	Preheat to 350° F; Maintain Preheat Temperature Throughout Welding Operation: Cool in still Air.	
FILLER ELECTRODE OR WIRE DIAMETER	First pass 3/32", Subsequent passes 1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Inconel No 92. Bare Rods	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (5 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	350° F (max)	350° F (max)
AMPERES	135-145	135-145
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	8" per hr (5 passes)	7" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) Cu Ni 70-30 316	-----	24,073 35,707	54,022 75,415	30 40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	32,769	54,765	27	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	29,480	55,276	31	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	33,104	56,415	26	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	33,653	55,548	25	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-80. Certified Procedures and Test Data - Specification No.59

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)MATERIAL A312-62T, Type 316 S.S.(specification) WELDED TO B111-61T, 70-30 Cu NiPIPE SIZE AND WALL THICKNESS 5" Schedule 80, 0.375" WallTHICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"FILLER METAL SPECIFICATION B304-56T, ERN62 and B295-54T, E3N12CHEMICAL ANALYSIS Chromium 14.0-17.0%, Nickel 67.0-70.0%INERT GAS COMPOSITION Argon Welding Grade, 99.99% Purity FLOW RATE 20 cfhTYPE BACKING USED Argon Gas PurgePREHEAT TREATMENT Preheat to 350° F; Maintain Preheat Temperature Throughout Welding Operation; Cool in Still AirFILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"TRADE NAME ROD USED TO OBTAIN DATA Inconel No. 92 Bare Rods and Inco-Weld "A" ElectrodesFOREHAND OR BACKHAND TECHNIQUE ForehandNORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psiSTRESS RELIEVING PROCEDURE NonePOSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-5	See Fig 3-6
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	350° F (max)	350° F (max)
AMPERES	First pass 140-150 Subsequent passes 90-130	First pass 140-150 Subsequent passes 90-130
VOLTS	28-30	28-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>Cu Ni 70-30 316</u>	-----	<u>24,073</u> <u>35,707</u>	<u>54,022</u> <u>75,415</u>	<u>30</u> <u>40</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	29,435	53,964	25	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	31,660	54,877	28	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	28,715	53,550	29	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	31,995	54,590	27	P. M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-81. Certified Procedures and Test Data - Specification No.60



CERTIFIED PROCEDURE	
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc
MATERIAL	B241-55T, GS11A, 6061-T6 (specification) WELDED TO B241-55T, GS11A, 6061-T6
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/8"
FILLER METAL SPECIFICATION	B285-61T, ER5356
CHEMICAL ANALYSIS	Aluminum
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh
TYPE BACKING USED	Argon Gas Purge
PREHEAT TREATMENT	Preheat to 700° F; Maintain Preheat Temperature Throughout Welding Operation; Cool in Still Air
FILLER ELECTRODE OR WIRE DIAMETER	1/8"
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Alumar Bare Rods
FOREHAND OR BACKHAND TECHNIQUE	Forehand
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	40,000 psi
STRESS RELIEVING PROCEDURE	None
POSTHEAT TREATMENT	None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-3	See Fig 3-4
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	700° F (max)	700° F (max)
AMPERES	140-160	140-160
VOLTS	20-22	20-22
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	6" per hr (8 passes)	6" per hr (8 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	13,240	22,100	16.5	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	17,680	22,700	9.0	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	14,950	20,250	9.5	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	16,590	21,650	10.0	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	14,480	22,350	10.5	P.M.

GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-82. Certified Procedures and Test Data - Specification No.61

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** B241-55T, M1A, 3003AL (specification) **WELDED TO** B241-55T, M1A, 3003AL  
**PIPE SIZE AND WALL THICKNESS** 5" Schedule 80, 0.375" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/8"  
**FILLER METAL SPECIFICATION** B285-61T, ER4043  
**CHEMICAL ANALYSIS** ER4043 Aluminum  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** Preheat to 700° F; Maintain Preheat Temperature Throughout Welding Operation; Cool in Still Air  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Alumar Bare Rods  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 42,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-3	See Fig 3-4
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (8 passes)
<b>INTERPASS TEMPERATURE</b>	700° F (max)	700° F (max)
<b>AMPERES</b>	140-160	140-160
<b>VOLTS</b>	20-22	20-22
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	6" per hr (8 passes)	6" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	9,080	16,578	30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	10,716	16,160	26	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	11,163	15,158	29	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	11,045	15,359	28	P. M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	11,287	17,260	20	Weld

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-83. Certified Procedures and Test Data - Specification No.62

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc	
MATERIAL	B241-55T, M1A, 3003 (specification)	WELDED TO B241-55T, GS11A, 6061-T6
PIPE SIZE AND WALL THICKNESS	5" Schedule 80, 0.375" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 3/8"	
FILLER METAL SPECIFICATION	B285-61T, ER4043	
CHEMICAL ANALYSIS	ER4043 Aluminum	
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity	FLOW RATE 20 cfm
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	Preheat to 700° F; Maintain Preheat Temperature Throughout Welding Operation: Cool in Still Air	
FILLER ELECTRODE OR WIRE DIAMETER	1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Alumar Bare Rods	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	42,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-3	See Fig 3-4
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (8 passes)
INTERPASS TEMPERATURE	700° F (max)	700° F (max)
AMPERES	140-160	140-160
VOLTS	20-22	20-22
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	6" per hr (8 passes)	6" per hr (8 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <sup>6061-T6</sup> M1A 3003	-----	13,240 9,080	22,100 16,578	16.5 30	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	9,879	16,703	22	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	10,294	16,917	25	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	11,349	16,947	21	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	12,602	16,767	20	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-84. Certified Procedures and Test Data - Specification No.63

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL 36% Nickel Alloy (specification) WELDED TO 36% Nickel Alloy  
 PIPE SIZE AND WALL THICKNESS 4½" O. D. 0.250" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 1/2"  
 FILLER METAL SPECIFICATION Modified Invar Wire (refer to Para. 3-287)  
 CHEMICAL ANALYSIS Refer to Para. 3-289  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 15 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER 1/16"  
 TRADE NAME: ROD USED TO OBTAIN DATA Universal-Cyclops Steel Corp. Mod. Invar Wire (Ht. No. KH 3229)  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 70,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-7	See Fig 3-8
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (5 passes)	Multiple (6 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	60-90	60-90
VOLTS	24-26	24-26
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	8" per hr (5 passes)	7" per hr (6 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	69,400	72,500	33.5	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	54,650	72,400	31	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	59,400	72,600	32.5	Weld
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	53,900	72,200	33	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	52,900	71,600	32	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-85. Certified Procedures and Test Data - Specification No.64

**CERTIFIED PROCEDURE**

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** 36% Nickel Alloy (specification) **WELDED TO** 36% Nickel Alloy  
**PIPE SIZE AND WALL THICKNESS** 4½" O.D. 0.250" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 1/16" through 1/2"  
**FILLER METAL SPECIFICATION** Modified Invar Wire (Refer to Para 3-287) and MIL-E-22200/3, MIL-4NIA  
**CHEMICAL ANALYSIS** Modified Invar Wire (Refer to Para. 3-289) and Nickel 68%, Chromium 13-17%, Iron 6-12%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First Pass 1/16", Subsequent Passes 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Universal-Cylops Steel Corp. Invar Wire Arcos Corp. Electrodes.  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-7	See Fig 3-8
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (4 passes)	Multiple (6 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	60-90	60-90
<b>VOLTS</b>	22-28	22-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	10" per hr (4 passes)	8" per hr (6 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	69,400	72,500	33.5	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	51,850	71,500	29	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	53,500	72,500	31.5	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	53,400	73,900	29	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	55,150	74,500	29	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-86. Certified Procedures and Test Data - Specification No.65

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc  
**MATERIAL** 36% Nickel Alloy (specification) **WELDED TO** 36% Nickel Alloy  
**PIPE SIZE AND WALL THICKNESS** 4½" OD, 0.250" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 1/16" through 1/2"  
**FILLER METAL SPECIFICATION** Modified Invar Wire (Refer to Para 3-287) and B304-56T, ERN 62  
**CHEMICAL ANALYSIS** Modified Invar Wire (Refer to Para 3-289) and Nickel 70% (min.), Chromium 14-17%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** None  
**FILLER ELECTRODE OR WIRE DIAMETER** First pass 1/8", Subsequent passes 1/16"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rod, Universal-Cylops Steel Corp. Invar Wire  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 70,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-9	See Fig 3-10
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (5 passes)	Multiple (6 passes)
<b>INTERPASS TEMPERATURE</b>	300° F (max)	300° F (max)
<b>AMPERES</b>	55-80	60-90
<b>VOLTS</b>	22-26	22-26
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	8" per hr (5 passes)	6" Per hr (6 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
<b>PARENT METAL(S)</b>	-----	69,400	72,500	33.5	-----
<b>VERTICAL PIPE AXIS, WELD HORIZONTAL</b>	1	57,300	74,300	32	Weld
<b>VERTICAL PIPE AXIS, WELD HORIZONTAL</b>	2	51,200	72,900	32.5	Weld
<b>HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT</b>	1	53,000	72,800	31	Weld
<b>HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT</b>	2	52,750	72,500	32	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
<b>VERTICAL PIPE AXIS, WELD HORIZONTAL</b>	1 Root	Good	3 Root	Good
<b>VERTICAL PIPE AXIS, WELD HORIZONTAL</b>	2 Face	Good	4 Face	Good
<b>HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT</b>	1 Root	Good	3 Root	Good
<b>HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT</b>	2 Face	Good	4 Face	Good

Figure 3-87. Certified Procedures and Test Data - Specification No.66

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL 36% Nickel Alloy (specification) WELDED TO 36% Nickel Alloy  
 PIPE SIZE AND WALL THICKNESS 4 1/2" OD, 0.250" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 1/2"  
 FILLER METAL SPECIFICATION B-304-56T, ERN62, and MIL-E-22200/3, MIL-4NIA  
 CHEMICAL ANALYSIS Nickel 68% (min), Chromium 13-17%, Iron 6-12%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods and Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-9	See Fig 3-10
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (6 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	60-90	60-90
VOLTS	22-28	22-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (6 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	69,400	72,500	33.5	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	52,750	74,300	32	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	51,900	74,400	30	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	52,800	71,100	32.5	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	51,250	71,400	31.5	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-88. Certified Procedures and Test Data - Specification No.67

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc

MATERIAL 36% Nickel Alloy (specification) WELDED TO A312-62T, Type 304

PIPE SIZE AND WALL THICKNESS 4½ OD, 0.250 Wall

THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 1/2"

FILLER METAL SPECIFICATION B304-56T, ERN 62

CHEMICAL ANALYSIS Nickel 70% (min), Chromium 14-17%, Iron 6-10%

INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh

TYPE BACKING USED Argon Gas Purge

PREHEAT TREATMENT None

FILLER ELECTRODE OR WIRE DIAMETER 3/32"

TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods

FOREHAND OR BACKHAND TECHNIQUE Forehand

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi

STRESS RELIEVING PROCEDURE None

POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-7	See Fig 3-8
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (5 passes)	Multiple (7 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	90-105	90-105
VOLTS	26-30	26-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (5 passes)	8" per hr (7 passes)

TEST DATA  
REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>36% Nickel 304</u>	-----	<u>69,400</u> <u>87,400</u>	<u>72,500</u> <u>81,000</u>	<u>33.5</u> <u>63.5</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	50,250	70,900	32	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	51,750	74,000	32	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	51,750	74,000	32	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	54,200	76,150	33.5	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-89. Certified Procedures and Test Data - Specification No.68



## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL 36% Nickel Alloy (specification) WELDED TO A312-62T, Type 304  
 PIPE SIZE AND WALL THICKNESS 4½ OD, 0.250" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 1/2"  
 FILLER METAL SPECIFICATION B304-62T, ERN62, and MIL-E-22200/3, MIL-4NIA  
 CHEMICAL ANALYSIS Nickel 68% (min), Chromium 13-17%, Iron 6-12%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 15 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rod and Covered Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-7	See Fig 3-8
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (6 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	90-105	90-110
VOLTS	27-29	27-29
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (6 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>36% Nickel 304</u>	-----	<u>69,400</u> <u>67,400</u>	<u>72,500</u> <u>81,000</u>	<u>33.5</u> <u>63.5</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	50,800	75,700	33	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	54,400	74,750	33.5	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	44,000	80,400	32.5	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	48,000	76,600	31.5	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-90. Certified Procedures and Test Data - Specification No.69

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc  
 MATERIAL 36% Nickel Alloy (specification) WELDED TO A312-62T, Type 304  
 PIPE SIZE AND WALL THICKNESS 4½ OD, 0.250" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 1/2"  
 FILLER METAL SPECIFICATION B304-62T, ERN62  
 CHEMICAL ANALYSIS Nickel 70% (min), Chromium 14-17%, Iron 6-10%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 15 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT None  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 1/8", Subsequent passes 3/32"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rods  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-9	See Fig 3-10
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (5 passes)	Multiple (7 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	90-105	90-105
VOLTS	26-30	26-30
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (5 passes)	8" per hr (7 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>36% Nickel 304</u>	-----	69,400 67,400	72,500 81,000	33.5 63.5	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	49,250	73,650	33	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	50,000	76,300	31.5	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	43,500	80,800	33.5	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	50,700	73,000	32.5	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-91. Certified Procedures and Test Data - Specification No. 70

CERTIFIED PROCEDURE		
WELDING PROCESS	Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)	
MATERIAL	36% Nickel Alloy (specification)	WELDED TO A312-62T, Type 304
PIPE SIZE AND WALL THICKNESS	4½ OD, 0.250" Wall	
THICKNESS RANGE THIS TEST QUALIFIES	1/16" through 1/2"	
FILLER METAL SPECIFICATION	B304-62T, ERN62, and MIL-E-22200/3, MIL-4NIA	
CHEMICAL ANALYSIS	Nickel 68% (min), Chromium 13-17%, Iron 6-10%	
INERT GAS COMPOSITION	Argon Welding Grade 99.99% Purity	FLOW RATE 15 cfm
TYPE BACKING USED	Argon Gas Purge	
PREHEAT TREATMENT	None	
FILLER ELECTRODE OR WIRE DIAMETER	1/8"	
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Corp. Bare Rod and Covered Electrodes	
FOREHAND OR BACKHAND TECHNIQUE	Forehand	
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	80,000 psi	
STRESS RELIEVING PROCEDURE	None	
POSTHEAT TREATMENT	None	

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-9	See Fig 3-10
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (4 passes)	Multiple (6 passes)
INTERPASS TEMPERATURE	300° F (max)	300° F (max)
AMPERES	90-105	90-110
VOLTS	26-28	27-29
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	10" per hr (4 passes)	8" per hr (6 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) 36% Nickel 304	-----	69,400 67,400	72,500 81,000	33.5 63.5	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	52,150	75,000	32	P. M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	55,600	76,500	33	P. M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	49,800	73,400	33	Weld
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	51,800	74,600	32	P. M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Root	Good	3 Root	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Face	Good	4 Face	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Root	Good	3 Root	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Face	Good	4 Face	Good

Figure 3-92. Certified Procedures and Test Data - Specification No, 71

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A106-62T, GR. B Nickel Lined (specification) WELDED TO A106-62T, GR. B. Nickel Lined  
 PIPE SIZE AND WALL THICKNESS 2 1/2" XX, 0.552" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310 and A298-62T, E310-16  
 CHEMICAL ANALYSIS Chromium 25-28%, Nickel 20-22%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT Preheat to 450° F. (min), 500° F. (max) For First pass; Lower to 400° F. for Subsequent passes; Maintain Temperature  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rod and Covered Electrode  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None, Allow Completed Weld to Cool in Still Air

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-12	See Fig 3-13
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (10 passes)
INTERPASS TEMPERATURE	400° F (max) Cool to 400° F in Still Air Between Passes	400° F (max) Cool to 400° F in Still Air Between Passes
AMPERES	90-105	90-115
VOLTS	22-28	22-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	7" per hr (8 passes)	5" per hr (10 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	66,000	77,500	17	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	66,500	78,600	18	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	67,000	79,000	17.5	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	65,600	75,000	18.5	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	66,100	76,600	16	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Side	Good	3 Side	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Side	Good	4 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Side	Good	3 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Side	Good	4 Side	Good

Figure 3-93. Certified Procedures and Test Data - Specification No. 72

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A106-62T, GR. B, Nickel Lined (specification) WELDED TO A106-62T, GR. B, Nickel Lined  
 PIPE SIZE AND WALL THICKNESS 2 1/2" XX, 0.552 Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310, and A298-62T, E310-16  
 CHEMICAL ANALYSIS Chromium 25-28%, Nickel 20-22%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% Purity FLOW RATE 20 cfh  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT Preheat to 450° F (min), 500° F (max) For First Pass; Lower to 400° F For Subsequent Passes; Maintain Temperature  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rod and Covered Electrode  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None, Allow Completed Weld to Cool in Still Air

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-18	See Fig 3-19
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (10 passes)
INTERPASS TEMPERATURE	400° F (max) Cool to 400° F in Still Air Between Passes	400° F (max) Cool to 400° F in Still Air Between Passes
AMPERES	90-105	90-115
VOLTS	23-26	23-26
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	7" per hr (8 passes)	5" per hr (10 passes)

**TEST DATA  
REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S)	-----	66,000	77,500	17	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	67,000	75,600	16.5	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	68,000	77,000	16	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	66,500	76,900	16	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	68,300	76,900	18	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Side	Good	3 Side	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Side	Good	4 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Side	Good	3 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Side	Good	4 Side	Good

Figure 3-94. Certified Procedures and Test Data - Specification No.73

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
 MATERIAL A106-62T, GR. B Nickel Lined (specification) WELDED TO A312-62T, Type 316  
 PIPE SIZE AND WALL THICKNESS 2 1/2" XX, 0.552" Wall  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 3/4"  
 FILLER METAL SPECIFICATION A371-62T, ER310, and A298-62T, E310-16  
 CHEMICAL ANALYSIS Chromium 25-28%, Nickel 20-22%  
 INERT GAS COMPOSITION Argon Welding Grade 99.99% FLOW RATE 20 cfm  
 TYPE BACKING USED Argon Gas Purge  
 PREHEAT TREATMENT Preheat to 400° F (min); 450° F (max) For First pass; Lower to 300° F for Subsequent passes; Maintain Temperature  
 FILLER ELECTRODE OR WIRE DIAMETER First pass 3/32", Subsequent passes 1/8"  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Corp. Bare Rod and Covered Electrodes  
 FOREHAND OR BACKHAND TECHNIQUE Forehand  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000 psi  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None, Allow Completed Weld to Cool in Still Air

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
TYPE JOINT	See Fig 3-16	See Fig 3-17
POSITION OF GROOVE	Weld Overhead, Vertical, Upward, and Flat; Fixed Position	Weld Horizontal; Fixed Position
SINGLE OR MULTIPLE PASS	Multiple (8 passes)	Multiple (10 passes)
INTERPASS TEMPERATURE	300° F (max); Cool to 300° F in Still Air Between Passes	300° F (max) Cool to 300° F in Still Air Between Passes
AMPERES	90-105	90-115
VOLTS	22-28	22-28
AVERAGE WELDING RATE COMPLETE CROSS - SECTION	7" per hr (8 passes)	5" per hr (10 passes)

TEST DATA  
 REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>Gr. B Nickel Lined 316</u>	-----	<u>66,000</u> <u>38,707</u>	<u>77,500</u> <u>75,415</u>	<u>17.0</u> <u>40.0</u>	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	71,000	81,400	17.5	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	71,000	81,500	17.5	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	67,000	77,200	17.5	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	67,300	78,500	17.5	P.M.

## GUIDED BEND TEST - WELD COUPON

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Side	Good	3 Side	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Side	Good	4 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Side	Good	3 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Side	Good	4 Side	Good

Figure 3-95. Certified Procedures and Test Data - Specification No. 74

## CERTIFIED PROCEDURE

**WELDING PROCESS** Manual Inert-Gas Shielded Tungsten Arc (first pass) Manual Metal Arc (subsequent passes)  
**MATERIAL** A106-62T, GR. B Nickel Lined (specification) **WELDED TO** A312-62T, Type 316  
**PIPE SIZE AND WALL THICKNESS** 2½" XX, 0.552" Wall  
**THICKNESS RANGE THIS TEST QUALIFIES** 3/16" through 3/4"  
**FILLER METAL SPECIFICATION** A371-62T, ER310, and A298-62T, E310-16  
**CHEMICAL ANALYSIS** Chromium 25-28%, Nickel 20-22%  
**INERT GAS COMPOSITION** Argon Welding Grade 99.99% Purity **FLOW RATE** 20 cfh  
**TYPE BACKING USED** Argon Gas Purge  
**PREHEAT TREATMENT** Preheat to 400°F (min), 450°F (max) for First pass; Lower to 300°F For Subsequent passes; Maintain Temperature  
**FILLER ELECTRODE OR WIRE DIAMETER** 1/8"  
**TRADE NAME ROD USED TO OBTAIN DATA** Arcos Corp. Bare Rod and Covered Electrode  
**FOREHAND OR BACKHAND TECHNIQUE** Forehand  
**NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION** 80,000 psi  
**STRESS RELIEVING PROCEDURE** None  
**POSTHEAT TREATMENT** None, Allow completed weld to cool in still air.

	HORIZONTAL PIPE AXIS,	VERTICAL PIPE AXIS
<b>TYPE JOINT</b>	See Fig 3-18	See Fig 3-19
<b>POSITION OF GROOVE</b>	Weld Overhead, Vertical, Upward and Flat; Fixed Position	Weld Horizontal; Fixed Position
<b>SINGLE OR MULTIPLE PASS</b>	Multiple (8 passes)	Multiple (10 passes)
<b>INTERPASS TEMPERATURE</b>	300°F (max) Cool to 300°F in Still Air Between Passes	300°F (max) Cool to 300°F in Still Air Between Passes
<b>AMPERES</b>	90-105	90-115
<b>VOLTS</b>	22-28	22-28
<b>AVERAGE WELDING RATE COMPLETE CROSS - SECTION</b>	7" per hr (8 passes)	5" per hr (10 passes)

**TEST DATA**  
**REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN NO.	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY	LOCATION OF FAILURE
PARENT METAL(S) <u>GR B Nickel Lined 316</u>	-----	66,000 35,707	77,500 75,415	17 40	-----
VERTICAL PIPE AXIS, WELD HORIZONTAL	1	68,000	76,000	17	P.M.
VERTICAL PIPE AXIS, WELD HORIZONTAL	2	68,000	76,000	17	P.M.
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1	65,000	75,200	17	P.M.
HORIZONTAL PIPE AXIS WELD OVERHEAD, VERTICAL AND FLAT	2	66,100	76,500	18	P.M.

**GUIDED BEND TEST - WELD COUPON**

DESCRIPTION	TYPE BEND SPECIMEN NO.	RESULT	TYPE BEND SPECIMEN NO.	RESULT
VERTICAL PIPE AXIS, WELD HORIZONTAL	1 Side	Good	3 Side	Good
VERTICAL PIPE AXIS, WELD HORIZONTAL	2 Side	Good	4 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	1 Side	Good	3 Side	Good
HORIZONTAL PIPE AXIS, WELD OVERHEAD, VERTICAL AND FLAT	2 Side	Good	4 Side	Good

Figure 3-96. Certified Procedures and Test Data - Specification No.75





## SECTION IV

### NON-DESTRUCTIVE INSPECTION BY ULTRASONIC, AND EDDY CURRENT METHODS

#### 4-1. GENERAL.

4-2. The information contained in this section describes ultrasonic and eddy current inspection methods for welds in high pressure and cryogenic systems; also qualifications and certification requirements for personnel engaged in the inspection of welds in high pressure and cryogenic systems. That portion of the section covering qualification and verification requirements for inspection personnel is based on recommendations by the Technical Council of the Society for Non-Destructive Testing.

#### 4-3. PRINCIPLES OF ULTRASONIC INSPECTION.

4-4. **ULTRASONIC PULSE-ECHO INSPECTION.** Ultrasonic pulse-echo equipment generates short pulses of high frequency electrical energy which are transmitted to a piezoelectric or electrostrictive disc. This converts the electrical energy into mechanical vibrations for transmission into the material under test. This beam of ultrasound will reflect from discontinuities and other reflecting surfaces. The reflected pulses are received by a second or the same piezoelectric or electrostrictive disc, converted into electrical energy, and are amplified and displayed on an oscilloscope. In standard equipment the trace on the oscilloscope screen is vertically deflected by the pulses. Since the horizontal deflection of the trace is a linear function of time, the various reflections are displayed in time se-

quence and their distance from the transmitting transducer can be determined. This display system is generally referred to as "A-scan." A display system whereby a cross section of the material is presented is referred to as "B-scan." A display system whereby an area is presented is referred to as "C-scan." Figure 4-1 illustrates block diagram of conventional ultrasonic equipment.

#### 4-5. THEORY OF SOUND.

4-6. **PROPOGATION OF SOUND.** Propagation of sound is caused by movement of molecules and is illustrated by placing a membrane in such a position that it is free to vibrate. When the membrane is not vibrating, the molecules on either side of the membrane possess like density. When the membrane vibrates, the membrane moves to one side and causes a higher density of molecules on that side and less density of molecules on the opposite side. This first movement of the membrane may be called the first-half period of vibration. When the membrane executes the second-half period of vibration, the exact opposite occurs; that is, what was the high density of molecules for the first-half period now has less density, and what was less density of molecules now has a high density of molecules. Movement of all molecules occur simultaneously in the immediate vicinity of a vibrating membrane.

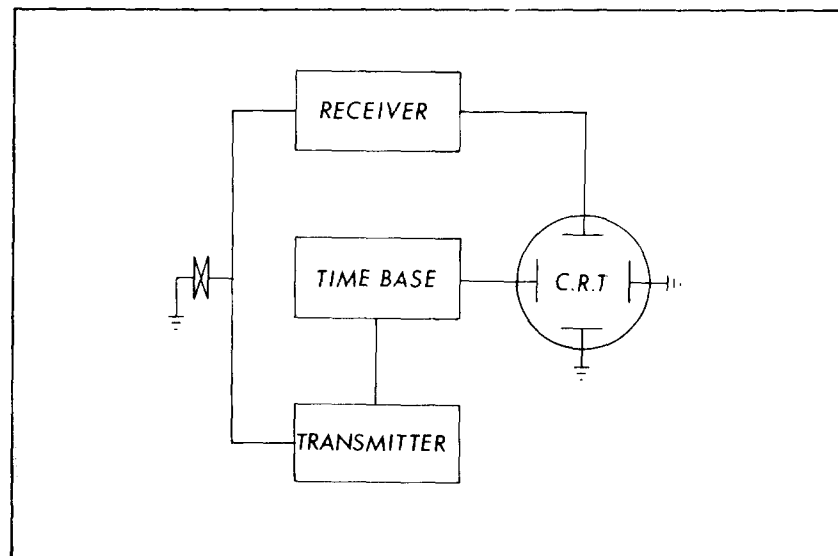


Figure 4-1. Block Diagram of Conventional Ultrasonic Equipment

4-7. Figure 4-2 illustrates wave fronts of equal pressure and at equal phase, which indicate that the wave fronts are spaced one or more wave lengths apart, provided that damping is not accounted for. Damping is the decrease in the wave amplitude due to the structure of the material with respect to time. Figure 4-2 also illustrates the relationship between the wave length and the sound velocity. The wave length is equal to the distance over which the compression or rarefaction propagates during each period.

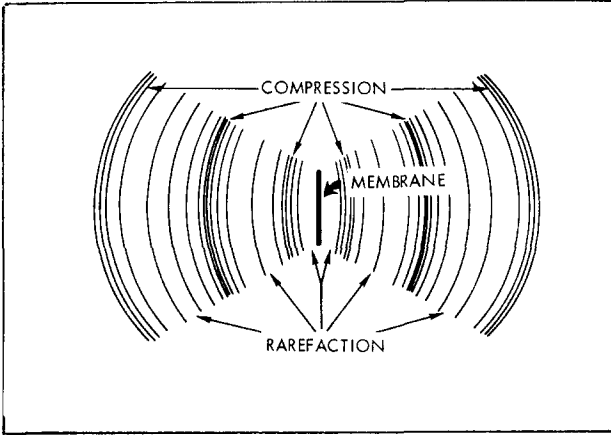


Figure 4-2. Relationship of Wave Fronts of Equal Pressure and Phase, Wave Length and Sound Velocity

$$C = f \cdot \lambda$$

Where: C = Sound velocity in meters/seconds

f = Frequency in cycles/second

$\lambda$  = Wave length in meters

Sound velocity is indicated by the capital letter C. Various wave forms are indicated by suffixing a lower case alphabetical letter to the sound velocity symbol as a subscript:

- Longitudinal velocity =  $C_L$
- Transverse velocity =  $C_t$
- Surface wave velocity =  $C_r$
- Lamb wave - asymmetrical =  $C_a$
- Lamb wave - symmetrical =  $C_s$

4-8. Sound velocity is influenced by the temperature in a material. As the temperature in a material increases, the sound velocity also increases in proportion within its aggregate condition. Figure E-1 shows sound velocities in solids and Figure E-2 shows sound velocities in water at given temperatures.

4-9. SOUND WAVE FORMS. Not all sound waves can be applied to non-destructive testing at the present time. Wave forms that are applicable to non-destructive testing are; longitudinal (or compression) waves, transverse (or shear) waves, surface (or Rayleigh) waves, and Lamb (or plate) waves.

4-10. LONGITUDINAL WAVE FORM. Sound waves discussed in paragraph 4-6 are longitudinal waves. In the movement of longitudinal waves, the movement of particles is in the same direction as the direction of propagation of the wave. Figure 4-3 illustrates schematically the movement of particles in the same direction as the direction of propagation of the wave. Figure 4-3 also shows the areas of condensation and of rarefaction which are also illustrated in Figure 4-2.

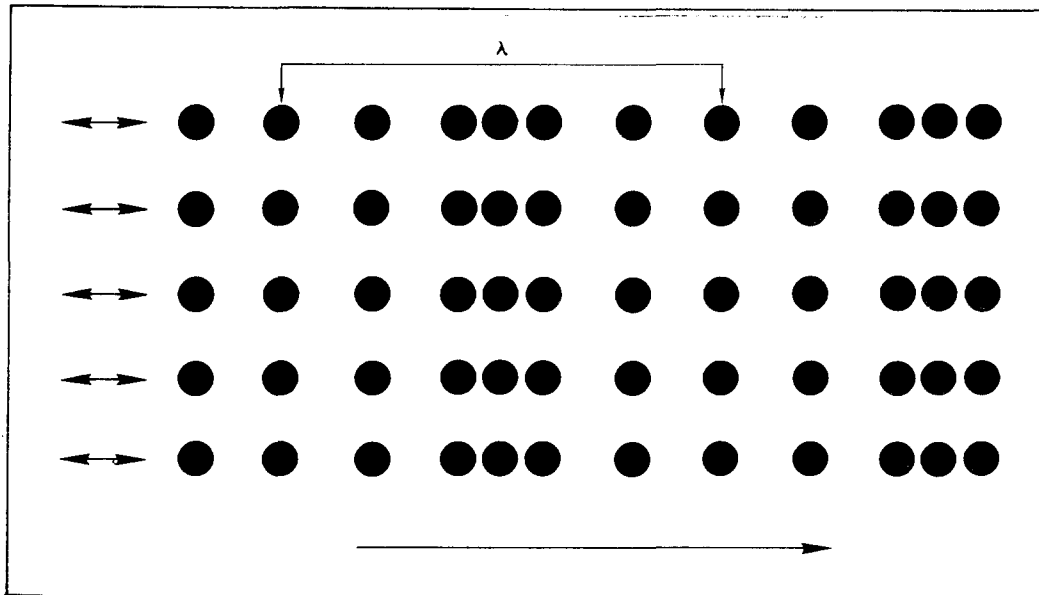


Figure 4-3. Movement of Particles in Longitudinal Waves

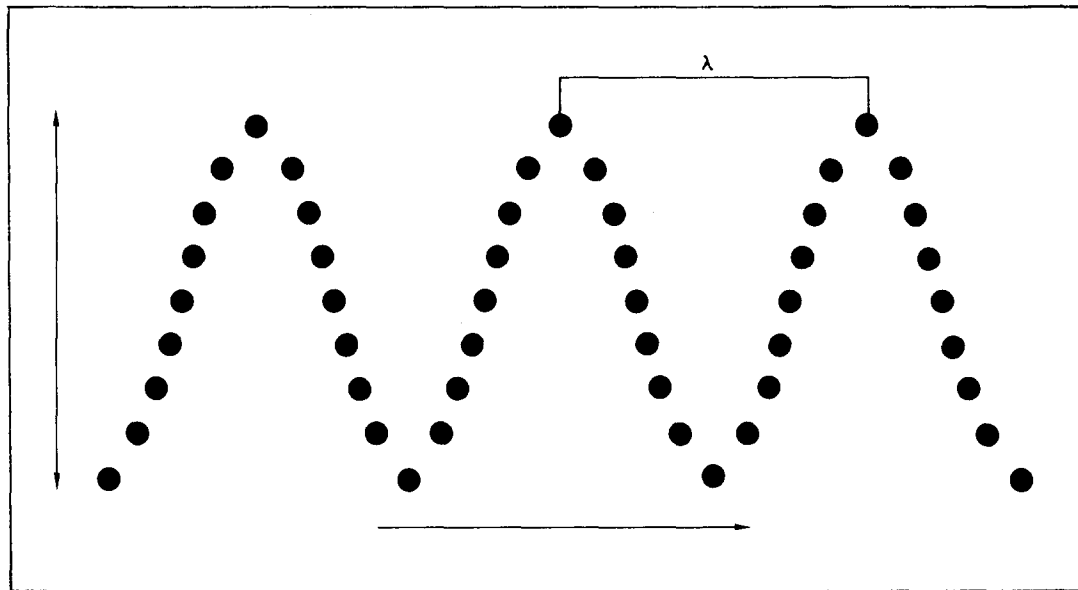


Figure 4-4. Movement of Particles in Transverse Waves

4-11. **TRANSVERSE WAVE FORM.** In the movement of transverse waves, the particles are perpendicular to the direction of the propagation of the wave. Transverse waves can be generated only in material having sufficient elastic properties. Transverse waves cannot be generated in liquids or gases. Figure 4-4 illustrates the movement of particles perpendicular to the direction of propagation of the wave.

4-12. **SURFACE WAVE FORM.** Figure 4-5 illustrates a surface wave shown in a steel, i.e., the vibrational movement of the surface. The deformation of the surface is not a true sine wave. The depth of penetration of a surface wave is no more than one wave length. It is not possible to generate a surface wave in a material when the thickness of the material approaches one wave length.

4-13. **LAMB WAVE FORM.** The waves generated in a material of which the thickness of the material approaches one wave length are called "plate" waves, some of which waves are known also as Lamb waves. Lamb waves occur in two basic types of waves; symmetrical waves and asymmetrical waves. The particles in the neutral zone of symmetrical Lamb waves carry out a longitudinal vibration. Particles in the neutral zone of an asymmetrical Lamb wave carry out transverse vibrations. In both symmetrical and asymmetrical Lamb waves, the remaining particles follow an elliptical path as illustrated in figures 4-6 and 4-7.

4-14. **REFLECTION.** A reflection occurs when a sound beam strikes an interface between two different media. The angles of incident and of reflected sound are equal. The behavior of sound in this respect is similar to the reflection of light. (See Figure 4-8). Part of the sound beam is not reflected but enters the second medium. The amount of reflected energy depends upon the acoustical impedance of both materials as expressed in the formula:

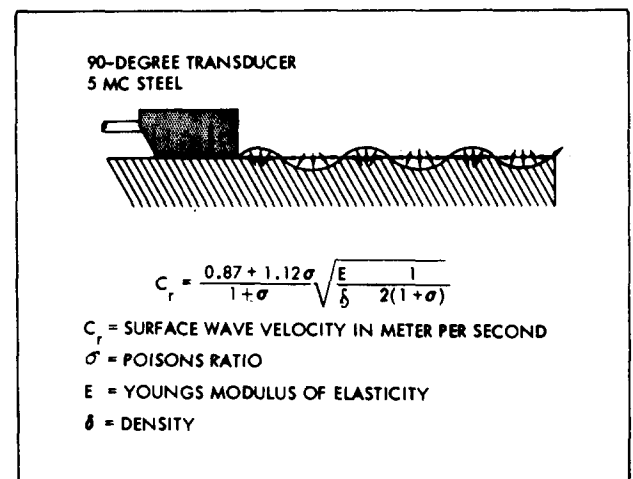


Figure 4-5. Movement of a Surface Wave in Steel

$$Z = \delta C$$

Where:  $Z$  = Acoustical impedance  $\times 10^6$  KG/M<sup>2</sup> - second

$\delta$  = Density  $\times 10^3$  KG/M<sup>3</sup>

$C$  = Sound velocity M/second

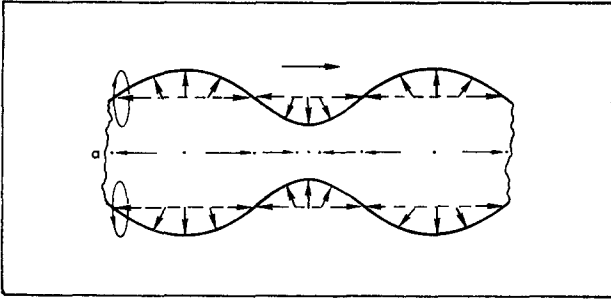


Figure 4-6. Flow of Particles in a Symmetrical Lamb Wave

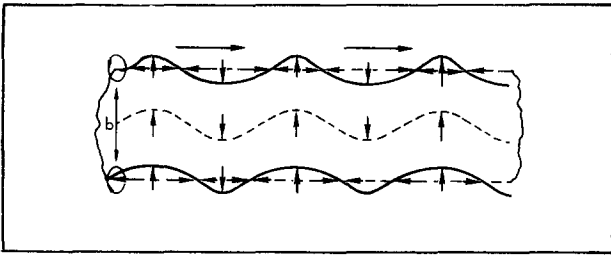


Figure 4-7. Flow of Particles in an Asymmetrical Lamb Wave

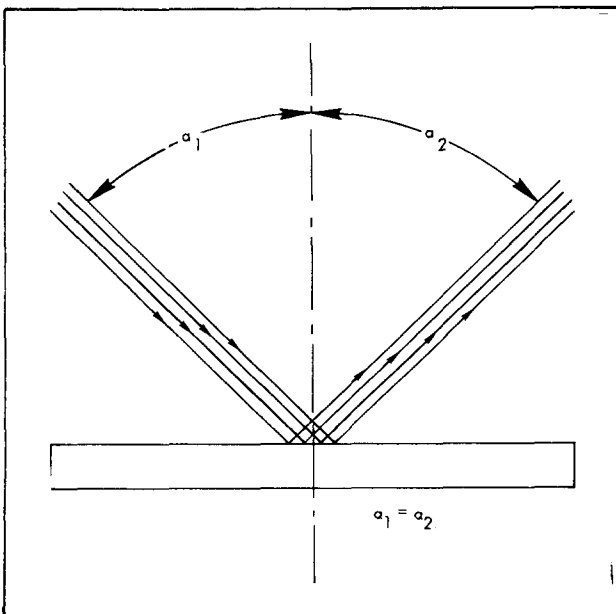


Figure 4-8. Angle of Incidence is Equal to Angle of Reflection

4-15. The amount of reflected energy for normal incidence is determined by:  
(See Figure 4-9).

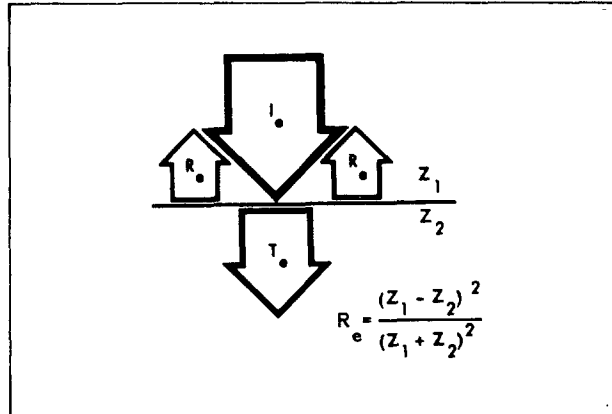


Figure 4-9. Schematic Presentation of Reflected Sound Energy

$$R_e = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2} = \frac{W_r}{W_i}$$

$I_e$  = Total input energy  
 $(Z_1 \pm Z_2)^2$

$W_r$  = Reflected beam intensity

$R_e$  = Reflected energy coefficient

$W_i$  = Incident intensity

$Z_1$  = Acoustical impedance in first medium

$W_t$  = Transmitted beam intensity

$Z_2$  = Acoustical impedance in second medium

$t_e$  = Remaining energy transmitted into medium  $Z_2$

$T_c$  = Transmission coefficient

$$T_c = \frac{W_t}{W_i} = \frac{4Z_2Z_1}{(Z_2 + Z_1)^2}$$

$$R_e + T_c = 1.0$$

The reflected energy can be converted into the amplitude of the particle motion. The reflected energy is directly proportional to the square of the amplitude. Thus the amplitude of a reflection is determined by:

$$R_a = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

Where:  $R_a$  = Amplitude of reflection

$Z$  = Acoustical impedance

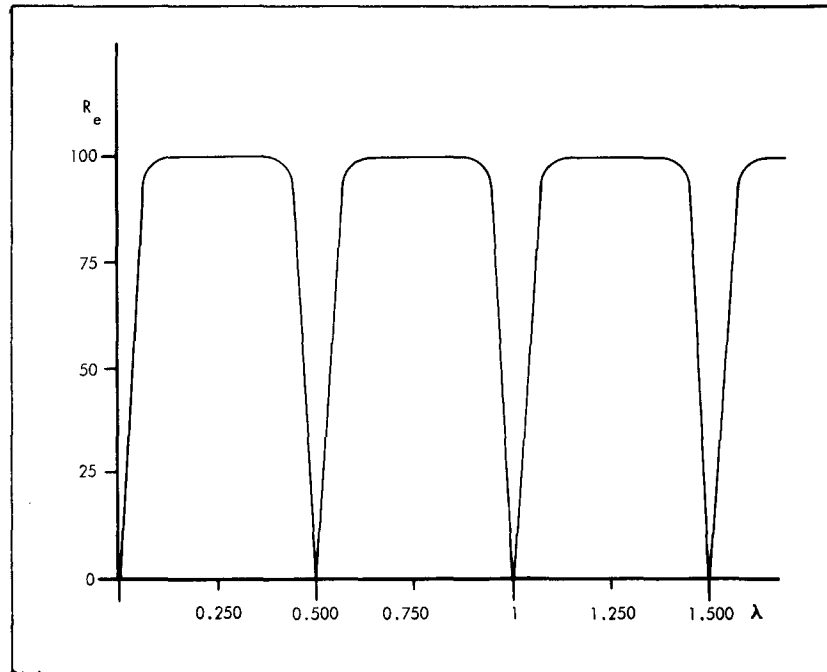


Figure 4-10. Graphic Presentation of the Relationship Between Wavelength and Transmission of Sound Energy Through Thin Films

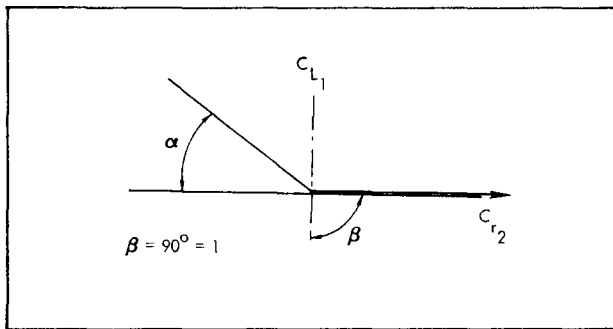


Figure 4-11. Schematic Presentation of a Longitudinal Wave Refracting into a Surface Wave

4-16. A table of reflection factors for amplitude in percentage is given in Figure E-3. Reflection against thin films changes the formula shown in Figure E-3, because of film thickness and the frequency influence the magnitude of reflected energy. Figure 4-10 shows that maximum reflection occurs when the film thickness equals 0.25, 0.75, and 1.25 (of the wavelength  $\lambda$ ) Maximum transmission occurs when the film thickness equals 0.5, 1.0, and 1.5 wavelength ( $\lambda$ ).

4-17. Refraction occurs when a sound beam strikes the interface at an angle. The angle of refraction is determined by the angle of incidence and the sound velocity in the two media according to the following formula: (See figure 4-12).

$$\frac{\sin \alpha}{\sin \beta} = \frac{c_1}{c_2}$$

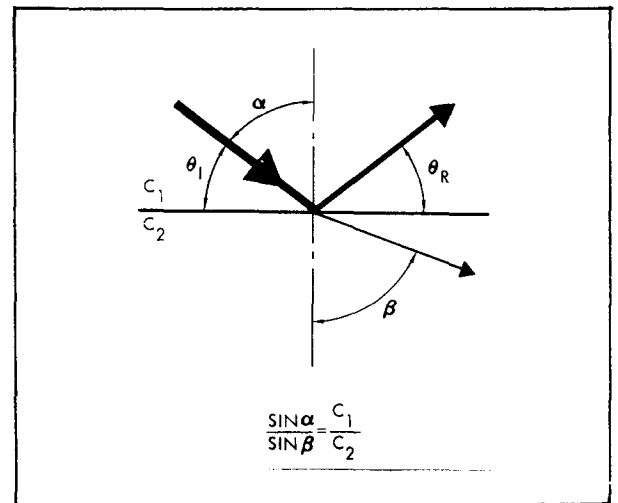


Figure 4-12. Schematic Presentation of Snell's Law of Refraction

- Where:
- $\alpha$  = Angle of incidence from the vertical
  - $\beta$  = Angle of refraction from the vertical
  - C = Sound velocity M/S
  - $\theta_1$  = Angle of incidence from horizontal
  - $\theta_R$  = Angle of reflection from horizontal

EXAMPLE: An angle transducer is marked 55° Fe.  
What is the refracted angle in aluminum?

$$\frac{\sin \alpha}{\sin \beta} = \frac{C_1}{C_2}; \frac{\sin 55^\circ}{\sin \beta} = \frac{3240}{3130}$$

$$\beta = \sin^{-1} 0.791 = 52.3^\circ$$

Depending upon the angle of incidence and sound velocities, the sound beam refracts into longitudinal, transverse, or surface waves. The formula for this refraction is:

Transverse waves  
(Figure 4-13)  $\frac{\sin \alpha}{\sin \beta} = \frac{C_{L1}}{C_{t2}}$

Surface waves  
(Figure 4-11)  $\frac{\sin \alpha}{\sin \beta} = \frac{C_{L1}}{C_{r2}} = \frac{\sin \alpha}{1} = \frac{C_{L1}}{C_{r2}}$

The angles of refraction for various materials are listed in Figure E-4.

4-18. The near zone, or Fresnell zone, is that part of the sound beam which extends over an area at a limited distance in front of the piezoelectric disc. The length of the near zone is determined by the following formula: (See figure 4-14).

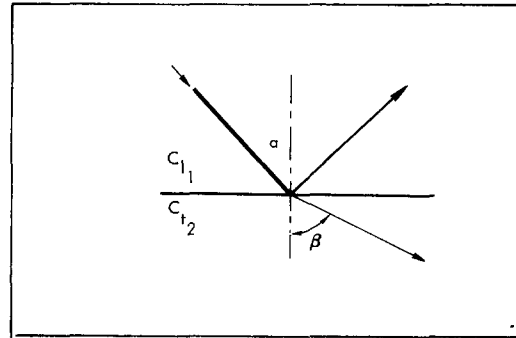


Figure 4-13. Schematic Presentation of a Longitudinal Wave Refracting into a Transverse Wave

$$L_o = \frac{D^2}{4\lambda} = .25 \frac{D^2 f}{C}$$

Where:

- $\lambda$  = Wave length - meter
- f = Frequency cycles/sec
- C = Sound velocity meters/sec
- $L_o$  = Near zone - meter
- D = Diameter of piezoelectric disc - meter

Localized areas of high and low intensity exist in the near zone due to interference. Accurate measurements therefore, are impossible in the near zone, but the detrimental effect can be overcome with a sound delay, as is the case with immersed inspection and through use of plexiglass wedge.

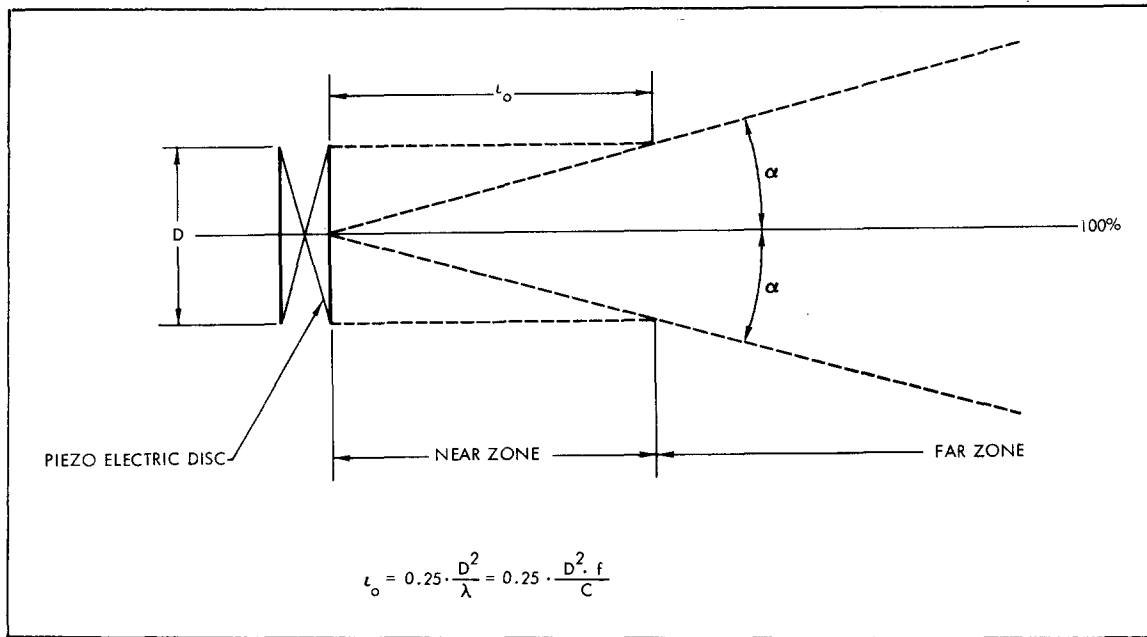


Figure 4-14. Schematic Presentation of Soundbeam Showing Near and Far Zone

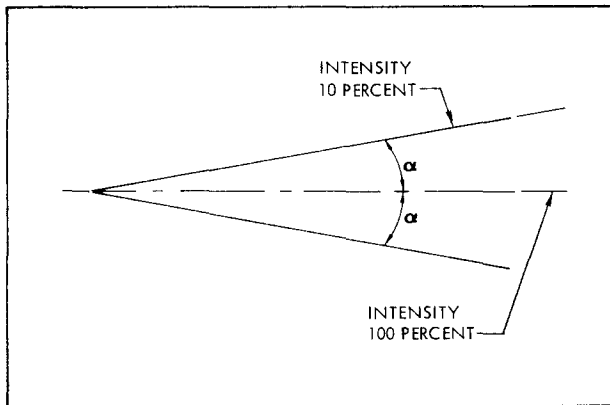


Figure 4-15. Divergence of Sound Beam

4-19. Divergence occurs in the far or Fraunhofer zone. Divergence is the natural spreading of the sound beam. The angle of divergence is determined by the diameter of the piezoelectric disc and the wave length. The sound intensity, through a cross-sectional area of the beam, varies from maximum in the center to a minimum along the sides of the spreading sound beam. There is a general reduction in sound intensity and for practical purposes 10% of the maximum intensity is used for actual divergence. (See Figure 4-15). This angle of divergence can be calculated by the following formula:

$$\sin \alpha = K \frac{\lambda}{D}$$

$\alpha$  = Angle of divergence

$\lambda$  = Wave length cm

$D$  = Diameter piezoelectric cm.

The value for K at intensities of 10, 30, 50 and 70 percent of maximum are 1.08, 0.76, 0.56 and 0.44, respectively (See figure 4-15).

4-20. Attenuation in solids is caused by damping and by dispersion of the sound energy. In dispersion of sound energy, attenuation can be attributed directly to very small heterogeneities in the material. Damping is caused by the conversion of sound energy into other forms of energy such as heat. Another form of attenuation is caused by the structure of the material. In a coarse-grained material, where the wave length approaches the grain size, dispersion of sound energy at the grain boundaries occurs. This action can be compared by driving in fog with headlights on; the light is dispersed in all directions. At a high gain setting of the ultrasonic instrument, it will display a "grass" effect on the cathode-ray tube. Defect reflections cannot be recognized in this display. The use of a

lower frequency (longer wave length) partially solves this problem. Total dispersion occurs when

$$\frac{\lambda}{d} = 1.08 \quad \begin{array}{l} \lambda - \text{wave length cm} \\ d - \text{diameter defect cm} \end{array}$$

as a result the detection of a small defect, which is possible at a high frequency need not be possible at a lower frequency. Example:

$$C = 6000 \text{ meters per second}$$

$$\lambda = \frac{C \text{ meters/sec}}{f \text{ cycles/sec}}$$

$$\lambda = \frac{6,000 \text{ M/S}}{5,000,000 \text{ c/s}} = 1.2 \text{ mm at } 5 \text{ mc}$$

$$\lambda = \frac{6,000 \text{ M/S}}{2,000,000 \text{ c/s}} = 3 \text{ mm at } 2 \text{ mc}$$

#### 4-21. GENERATION OF ULTRASOUND.

4-22. Magnetostriction. Magnetostriction is the phenomenon by which a change in length or volume is caused by a change in the magnetic flux density through some metals such as steel, cobalt, nickel, and their alloys. As the magnetic flux density is generated electrically, the magnetostrictive transducer transforms electrical energy into mechanical vibrations or mechanical vibrations into electrical energy. Such a transducer is composed of a metal core (a rod, a slotted laminated stack, or cylinder) and insulated electrical wiring. The transducer appears similar to a transformer in many respects. The most effective frequency range for such transducers is between 20 and 100 kilocycles. At higher frequencies, the construction of such a transducer is more difficult and the use of piezoelectric or electrostrictive materials is preferred. The size of a transducer becomes too great for practical use when operated in the lower frequencies. For example, a 600 c/s transducer would have a length of 15 feet for effective use because the length of a transducer is a function of its resonance frequency which is expressed as follows:

$$F_r = \frac{C}{2L}$$

Where:  $F_r$  = Resonance frequency - c/s

$C$  = Sound velocity - m/sec

$L$  = Length - meters

The following formula applies for a ring transducer:

$$F_r = \frac{C}{\pi d}$$

Where:  $d$  = Diameter of ring - meters

The excitation windings of the solenoid should provide a peak magnetic field of between 50 and 200 oersteds. The solenoid required for this type of transducer can be calculated as follows:

$$H = \frac{.4 \pi NI}{L}$$

Where:  $H$  = Magnetic field in oersted  
 $N$  = Number of turns in the solenoid  
 $I$  = Current in amperes  
 $L$  = Length of the magnetic path in cm

A typical magnetostrictive transducer is shown in Figure 4-16.

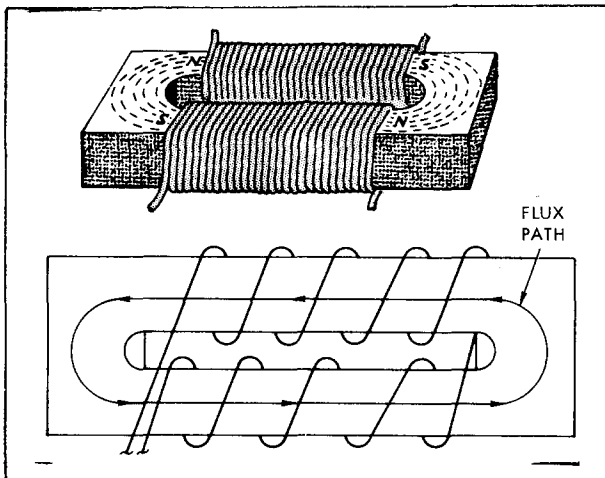


Figure 4-16. Typical Magnetostrictive Transducer

4-23. Piezoelectricity. Piezoelectricity is the phenomenon of generating electrical potentials when certain crystals are deformed. The most widely known materials having this property are quartz, Rochelle salt, and tourmaline. Hexagonal quartz, as found in nature, is very hard and extremely brittle. Rochelle salt is machined successfully but mechanical properties are not favorable. A typical piezoelectric crystal is shown in Figure 4-17.

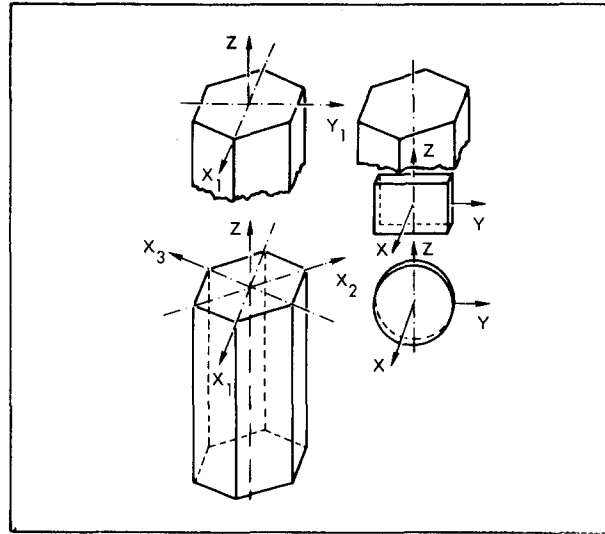


Figure 4-17. Piezoelectric Crystal

4-24. When a disc is cut out of a crystal perpendicular to the X axis, pressure along this axis will generate a potential between the two parallel surfaces. When an electric potential is applied to the crystal disc, deformation will occur. This effect is called the reverse piezoelectric effect. A crystal may also be cut perpendicular to the Y axis. When an alternating current is applied to a Y crystal, it will vibrate transversely. The output of a crystal is at a maximum when it is in resonance. As the resonance frequency depends upon the thickness of the crystal, cutting of the crystal must be precise. The resonance frequency of a crystal is determined by the formula:

$$F_r = \frac{C}{2t}$$

Where:  $C$  = Sound velocity meter per second

$F_r$  = Resonance frequency in cycles per second

$t$  = Thickness of X crystal or diameter (length) of Y crystal meters

4-25. The man-made compounds exhibiting piezoelectric properties are known as electrostrictive materials. These compounds are divided into two groups; compounds formed physically such as ceramics which includes barium titanate, lead zirconate, and lead metaniobate, and compounds formed chemically such as lithium sulphate. The ceramic materials have better mechanical properties than lithium sulphate. Lithium sulphate has a deliquesce property of absorbing water from the atmosphere.



4-26. The two active surfaces of the piezoelectric disc are made conductive by vaporizing layers of silver, aluminum, or chromium on them. The assembly, consisting of a piezoelectric disc, damping material, holder, and cable connector, comprises an ultrasonic transducer. The transducer must be combined with an impedance matching network in basically the same manner that a loud speaker is matched to an amplifier with a transformer. This impedance matching network is built in the transducer housing or in the cable connector. A schematic of a transducer is shown in Figure 4-18.

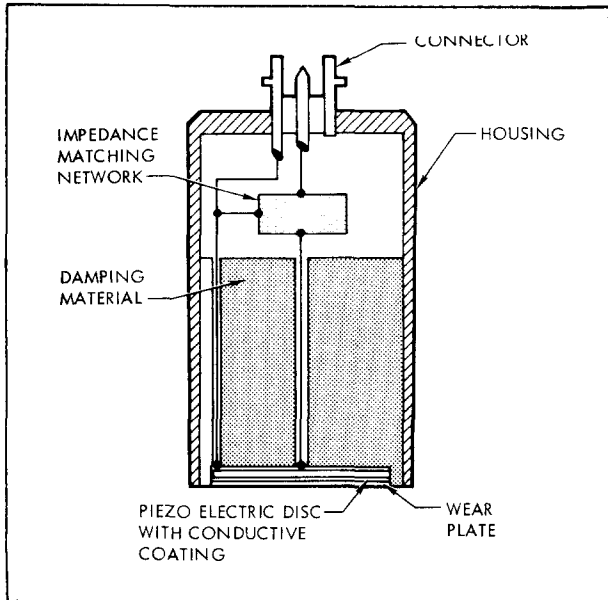


Figure 4-18. Schematic of Ultrasonic Transducer

4-27. A different impedance matching device is required for each piezoelectric material, frequency, size of disc and the output/input impedance of the ultrasonic instrument. The impedance matching network for contact transducers is different from that of immersed transducers. This is caused by the different acoustical impedance between a liquid (water) and any solid. Specific information on piezoelectrical material is required when designing impedance matching networks.

4-28. **COUPLANTS.** A couplant is required between the face of the transducer and the surface of the material under inspection to assure proper transmission of ultrasonic energy. Any liquid or plastic couplant having good acoustical properties is suitable. Oil is used as the most common couplant. Selection of the proper couplant is determined by characteristics of the test part such as surface finish, temperature of the specimen, further treatment of the specimen, and economy.

4-29. **SURFACE FINISHES.** An oil having a high viscosity should be used on rough surfaces. As the surface roughness increases the viscosity of the oil should also increase and inversely, an oil having a low viscosity should be used on smooth, polished surfaces. Thick couplants should be used on rough surfaces and thin, light-bodied couplants used on smooth surfaces.

4-30. **TEMPERATURES.** The temperature of the piezoelectric disc shall not exceed its depolarization temperature or the critical temperature of the adhesive used to bond the disc to the damping material. For high temperature application, cooling of the disc is essential. This cooling can be accomplished with water or silicone oils.

4-31. **ENVIRONMENT.**

### WARNING

Do not use oil or grease as a couplant in systems where oxidizing liquids or gasses are used since serious injury to personnel and damage to system will result.

4-32. **FURTHER TREATMENT OF SPECIMEN.** When a couplant is specified for use in testing and use of the couplant is not permitted due to certain circumstances, a selection may be made from liquids listed as follows:

- a. Water with rust preventative and wetting agent.
- b. Glycerine.
- c. Alcohol.
- d. Glucose (for rough surfaces).

4-33. **ECONOMY.** Because of availability, water is the most economical liquid couplant for mass inspection. Using water as a couplant is achieved by immersed scanning and by using a crystal fixed in a water jet. With these two methods, the detrimental effect of the near zone and dead zone are eliminated. However, a fixture is required to maintain the transducer perpendicular to the surface being inspected in order that the sound beam enter the material at an angle of 90 degrees with respect to the surface. Any deviation from the 90 degree angle will result in refraction showing complicated patterns.

4-34. A constant supply of liquid couplant can be supplied for angle transducers, by drilling a hole through the plexiglas block and making connections to a water or oil supply.

4-35. **DRY COUPLANTS.** A sheet of rubber may be used as a couplant but sheets must be exceedingly thin to prevent excessive damping. Pliable plastics may be used as couplants by rolling the plastic into a thin sheet and pressing the sheet into the surface irregularities of the part under inspection.

4-36. **INSPECTION EQUIPMENT AND ACCESSORIES.**

4-37. The ultrasonic instrument should fulfill the following basic requirements.

4-38. **CATHODE-RAY TUBE DISPLAY.** The cathode-ray tube display should have a linear horizontal display in order to determine the location of a reflecting surface as accurately as possible. The non-linearity of the time base must not exceed 2%.

4-39. **HIGH FREQUENCY PULSE AMPLIFIER.**

4-40. The high frequency pulse amplifier is used to amplify the relatively minute amounts of the electric energy caused by the returning sound paths. The high frequency pulse amplifier should have a linearity of at least 95% and be free of any clipping effect. The absence of a clipping effect will assure obtaining as accurate an attenuation pattern as possible of the inspected part. This enables determining defect size within physical limits.

4-41. **SCREEN DISPLAY OR PRESENTATION.** The presentation must be by video, radio frequency, or a combination of both. The pattern presented should be positive only to facilitate main viewing surface area (interpretation). Any noise generated by the equipment must not be visible on the cathode-ray tube display at high sensitivity levels. The dead zone is that area where no reflections can be visible on the viewing screen. The length of the dead zone, without the transducer attached, should not exceed 5.4 seconds. **HORIZONTAL POSITIONING** should be possible over a length of 25 microseconds, retaining a full length sweep on the cathode-ray tube display. **RANGE CONTROL** should be calibrated so that direct determination of the length of a sound path for both longitudinal, transverse and surface waves is possible. A change of sweep length should be possible without extensive calibration. The instrument shall have a calibrated sweep expansion and a regulated power supply.

4-42. **ULTRASONIC TRANSDUCERS.**

4-43. Ultrasonic transducers are divided into six groups as follows:

- a. Normal transducers.
- b. Angle transducers.
- c. Variable angle transducers.
- d. Transducers with separate transmitter and receiver.
- e. Transducers for immersed inspection.
- f. Focused transducers.

4-10

4-44. **PIEZOELECTRIC MATERIALS.** Some piezoelectric materials used in the manufacture of transducers are quartz, lithium sulphate, barium, lead zirconate, and lead metaniobate. Refer to paragraph 4-23 describing the use of these materials in ultrasonic testing.

4-45. **DAMPING MATERIALS.** Damping material for normal pulse echo transducers should present a high density surface on which the piezoelectric disc is mounted but which also dampens out the sound in a minimum length of material. Damping out the sound in a minimum length of material is a combination of acoustical properties and configuration. Damping material for angle transducers shall be completely bonded to the lucite or plexiglas wedge. The damping material and wedge material should have acoustical impedances as close as possible while damping properties should be higher. (See Figure 4-19). Some transducers contain serrated surfaces to disperse the sound instead of a damping material.

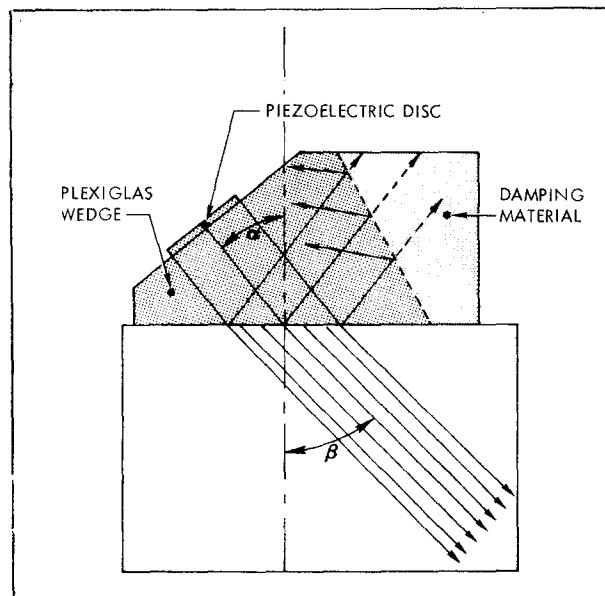


Figure 4-19. Schematic Showing Ultrasonic Angle Transducer with Damping Material

4-46. **MATCHING NETWORK.** The transducer should be matched to the ultrasonic instrument with an impedance matching network for optimum performance. A matching network can be built in the transducer or in the cable connector and should be identified as to whether located in the transducer or the cable connector. At higher frequencies the matching network gives protection against arcing through the piezoelectric disc.

4-47. **DISTURBING REFLECTIONS.** The transducer shall not be constructed as to have excessive ringing. The pulses should be no longer than two  $\mu$  seconds. Transducers in which lithium sulphate or other hygroscopic material is used should be completely sealed. The length of disturbing reflections for angle transducers shall not be longer than four  $\mu$  seconds in the part undergoing inspection.

**4-48. STANDARDIZATION OF ULTRASONIC EQUIPMENT.**

Branson Instruments, Inc.  
37 Brown House Road  
Stamford, Connecticut

Manufacturer of Pulse Echo  
Ultrasonic Equipment  
Resonance Ultrasonic Equipment

Equipment Origin: U. S. A.

1. Sonoray Flaw Detector Model 50C. -

Type:	Pulse Echo	-	Immersed and Contact
Frequency:	0.4 - 10 mc.		
Dimensions:	11"H x 7 5/8"W x 20 1/4"D		
Weight:	37 pounds		

Full complement of transducers and accessories available.  
Equipment suitable for weld inspection and thickness measurements.

2. Sonoray 30 Flaw/Thickness Tester (Battery Powered)

Type:	Pulse Echo	Contact
Frequency:	1 - 5 mc.	
Dimensions:	4 1/2"H x 9 1/2"W x 15"D	
Weight:	16 pounds (Including Batteries)	

Full complement of transducers available.  
Equipment suitable for weld inspection and thickness measurements.

3. Vidigage Thickness Gage Model 14B

Type:	Resonance
Frequency:	Ranges .75 to 30 mc. (9 Oscillators)
Dimensions:	14 1/2"H x 14 1/2"W x 23"D
Weight:	60 pounds

Full complement of transducers and accessories available.  
Equipment suitable for thickness measurements.

Krautkramer Ultrasonics, Inc.  
One Research Drive - Stratford, Connecticut

Origin: Germany

Parent Company: Dr. J. and H. Krautkraemer  
Gesellschaft Fuer Elektrophysik  
Luxemburgerstrasse 44g  
Cologne - West Germany

**Manufacturer of Pulse Echo Ultrasonic Equipment**

**1. Ultrasonic Instrument USK4 (Battery Powered)**

Type: Pulse Echo  
 Frequency: 1 - 6 mc  
 Dimensions: 4 1/2H x 7 1/2"W x 15"D  
 Weight: 10 pounds

Full complement of transducer and accessories available.  
 Equipment suitable for weld inspection and thickness measurements.

**2. Ultrasonic Instrument USM1 (Standard)**

Type: Pulse Echo Contact and Immersed  
 Frequency: 1 - 6 mc.  
 Dimensions: 13 3/4H x 9 1/4W x 21 1/2D  
 Weight: 44 pounds

Full complement of transducers and accessories available.  
 Equipment suitable for weld inspection and thickness measurements.

**3. Ultrasonic Instrument USIP 10W (Universal)**

Type: Pulse Echo Contact and Immersed  
 Frequency: 0.55 - 15 mc.  
 Dimensions: 13 3/4H x 9 1/4W x 21 1/2D  
 Weight: 49 pounds

Full complement of transducers and accessories available.  
 Equipment suitable for weld inspection and thickness measurements.

Magnaflux Corporation (Subsidiary of Champion Sparkplugs)  
 7300 West Lawrence Boulevard  
 Chicago 31, Illinois

Origin: USA

**Manufacturer of Pulse Echo and Resonance Ultrasonic Equipment**  
**Manufacturer of Eddy Current Instruments**

**1. Ultrasonic Instrument PS810**

Type: Pulse Echo Contact and Immersed  
 Frequency: 0.5 - 15 mc.  
 Dimensions: 13 1/4H x 9W x 23D  
 Weight: 43 pounds

Full complement of transducers and accessories available.  
 Equipment suitable for weld inspection and thickness measurements.

**2. Ultrasonic Instrument SO300**

Type: Resonance (Battery Powered)  
 Frequency: Range 750 kc - 4.5 mc Contact  
 Dimensions: 8 1/2H x 9 1/2W x 11 1/4D  
 Weight: 12 1/4 pounds  
 Dimensions Battery Case: 11"W x 10 1/2D x 3 1/2H  
 Weight Battery Case: 12 1/2 pounds

Full complement of transducers available.  
 Suitable for thickness measurements.

## 3. Eddy Current Instrument ED300

Frequency: 360 cps (Ferro magnetic material only)  
 Dimensions: 13"W x 9"H x 8"D  
 Weight: 24 1/2 pounds

## 4. Eddy Current Instrument ED500

Frequency: 50 kc - kc (Ferro Magnetic and non ferrous materials)  
 Dimensions: 15 1/2 x 8 1/2 x 10 1/2  
 Weight: 20 pounds

## 5. Eddy Current Instrument FM 120 (Battery Powered)

Frequency: 60 kc (Non ferrous materials only)  
 Conductivity 8 - 107 % I. A. C.  
 Range:  
 Dimensions: 4 1/8 x 9" x 6 1/2"  
 Weight: 5 pounds

Sperry Products  
 Division of Automation Industries, Inc.  
 Danbury, Connecticut

Manufacturer of Pulse Echo Ultrasonic Equipment

Origin: U. S. A.

## 1. Reflectoscope UM 715

Type: Pulse Echo Contact and Immersed  
 Frequency: Modular System - 40 kc up to 45 mc.  
 Dimensions: 7H x 15 1/2W x 19 7/8D  
 Weight:  
 Federal Stock No. 6635-996-1415

Full complement of transducers and accessories available.  
 Equipment suitable for weld inspection and thickness measurements.

## 2. Reflectoscope UM 721

Type: Pulse Echo Contact and Immersed  
 Frequency: Modular System - 40 kc up to 45 mc.  
 Dimensions: 7H x 15 1/2W x 19 7/8D  
 Weight:  
 Federal Stock No. 6635-996-1415

Full complement of transducers and accessories available.  
 Equipment suitable for weld inspection and thickness measurements.

4-49. **GENERAL.** The standardization of the equipment is a function to be performed by the inspection personnel by using a standardization or reference block. Standardization of ultrasonic equipment is important in determining the exact location of the defects. The location of a defect often indicates the kind of defect. In the manufacture of ultrasonic inspection equipment where all components must function identically as possible, a standard is required. Particular attention must be given to the sensitivity of the equipment. Sensitivity will vary with different instruments and with aging and continued use of the equipment and components. Differences in sensitivity of transducers of like manufacture will always prevail. The sensitivity is not uniform over the face of the average transducer. It may be required also that identical inspection procedures with similar parts be performed at various points on the parts.

4-50. **REFERENCE BLOCKS.** A reference block is required for the following reasons:

- a. To standardize the ultrasonic equipment and transducers.
- b. To reproduce a specific sensitivity setting and give a sound basis for the exchange of measuring data, where acoustical properties in sound media are the same.

c. To compare the sensitivity of ultrasonic equipment of different manufacture.

4-51. It is not possible to design a reference block which can be used for all purposes because many functions must be checked electronically. A rejected part from a lot may be retained and used as a calibration standard when inspecting other parts of the same lot, in lieu of using a reference block, and may be used to advantage over general purpose reference blocks. Various reference blocks are in use. All reference blocks, other than the International Institute of Welding reference blocks, are designed to give a direct relationship between the reflecting surface of a hole, or notch as an artificial defect and a flaw in the part undergoing inspection, which is to state that these reference blocks can be used to detect the size of a defect.

**NOTE**

A reference block cannot be used to detect the size of a defect directly.

4-52. The International Institute of Welding reference block can be used to standardize equipment for both normal (longitudinal) transducers, and angle (shear or transverse) transducers. Refer to Figure 4-20 for the example of the International Institute of Welding reference block.

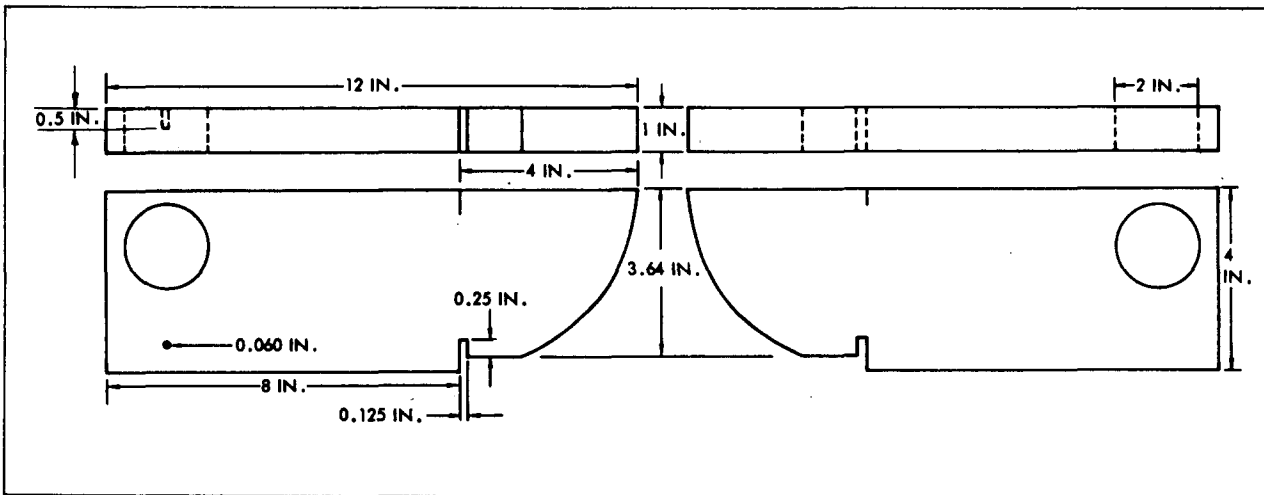


Figure 4-20. International Institute of Welding Ultrasonic Reference Block Adapted to American Measurement Standards

**4-53. STANDARDIZING FOR LONGITUDINAL WAVES WITH INTERNATIONAL INSTITUTE OF WELDING REFERENCE BLOCK.**

**4-54. LOW RANGE - UP TO 10 INCHES.**

- Position the transducer as illustrated in Figure 4-21.
- Depending upon the range setting, 5 or 10 back reflections should occur because the reference block is 1-inch thick.
- Adjust the first and second back reflection on the 1-inch and 2-inch mark with the FINE CONTROL RANGE and the ZERO POSITION CONTROL, if necessary.

**NOTE**

Do not standardize on a transmitting pulse, or a delay may cause inaccuracies. The start of the transmitting pulse does not coincide with the moment the sound beam enters the material. A small delay is inherent in ultrasonic equipment.

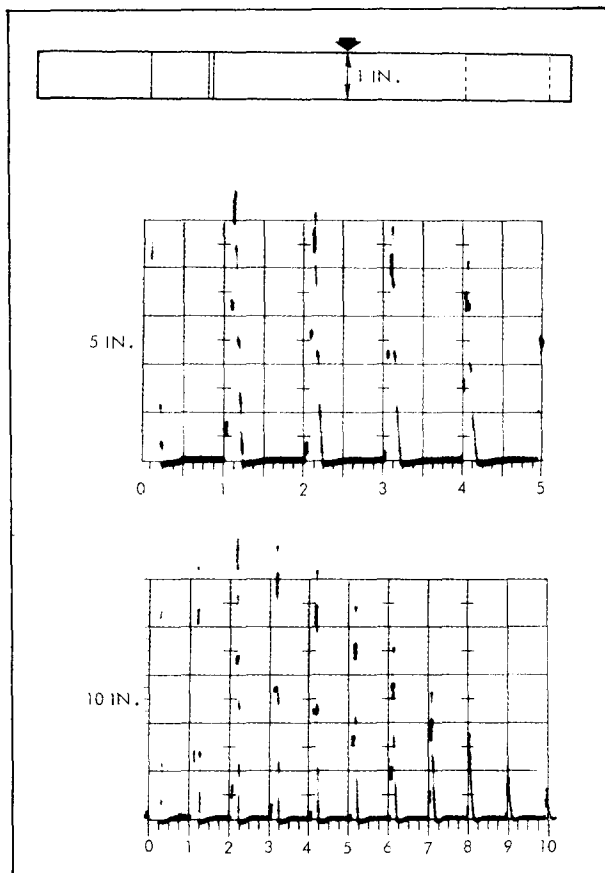


Figure 4-21. Positioning Transducer for Checking Longitudinal Waves - Low Range Up to 10 Inches

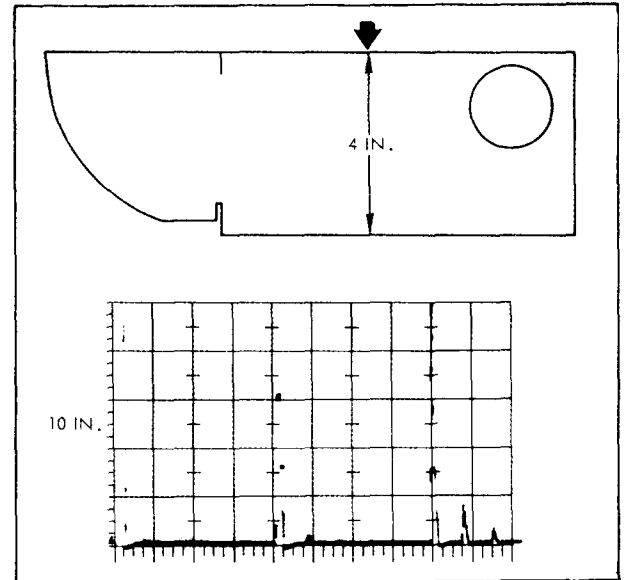


Figure 4-22. Positioning Transducer for Checking Longitudinal Waves - Range 10 Inches to 40 Inches

- With the first and second back reflections on the 1-inch and 2-inch marks, check that other back reflections are on their respective marks. Adjust with both FINE RANGE CONTROL and ZERO POSITION CONTROL, if necessary.

**4-55. RANGE FROM 10 INCHES TO 40 INCHES.**

- Position the transducer as illustrated in Figure 4-22.
- As the length of the sound path is 4 inches, the first back reflection occurs at the 4-inch mark and the second back reflection occurs at the 8-inch mark.
- Adjust the 4-inch and 8-inch reflections with the 4-inch and 8-inch marks, respectively, using FINE RANGE CONTROL and ZERO POSITION CONTROL. For the 40-inch range, adjust FINE RANGE CONTROL so that 10 back reflections are visible.

**4-56. RANGE FROM 40 INCHES TO 80 INCHES.**

- Position the transducer as illustrated in Figure 4-23.
- As the length of the sound path is 8 inches, the first back reflection will occur at the 8-inch mark.
- Adjust the 8-inch reflection with the 8-inch mark, using the FINE RANGE CONTROL and ZERO POSITION CONTROL.

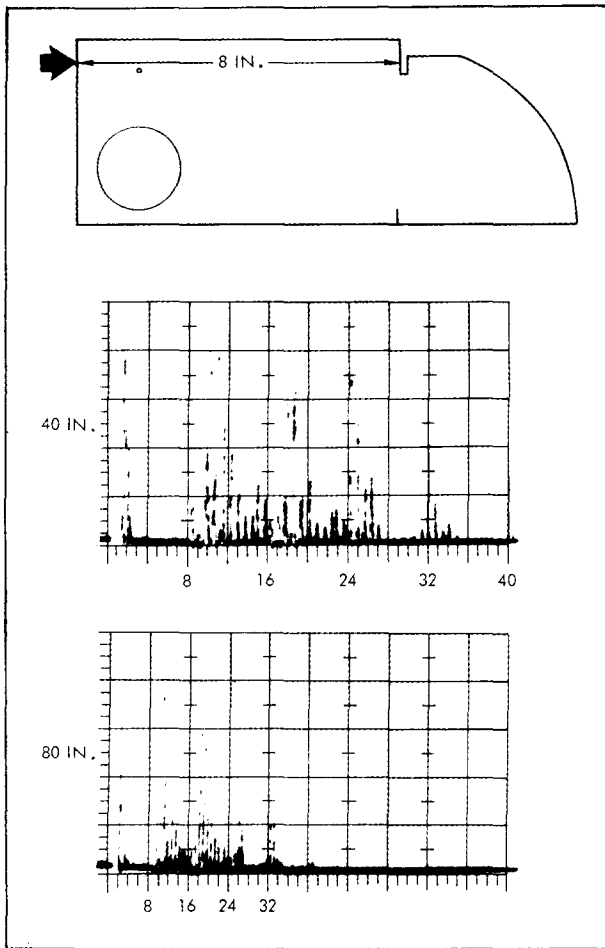


Figure 4-23. Positioning Transducer for Checking Longitudinal Waves - Range 40 Inches to 80 Inches

**4-57. RANGE 5 INCHES TO 10 INCHES AT LOWER FREQUENCIES.**

**NOTE**

When materials to be inspected have high damping properties, a lower frequency of one megacycle or less is required. It is difficult to standardize steel at this low frequency. A plexiglas disc has been inserted in the International Institute of Welding reference block. The thickness of the disc is equivalent to a 2-inch sound path in steel.

- a. Position the transducer as illustrated in Figure 4-24.
- b. The first back reflection will occur at the 2-inch mark, the second back reflection will occur at the 4-inch mark, and the third back reflection at the 6-inch mark, etc.
- c. Adjust the back reflections with their respective marks, using the FINE RANGE CONTROL and ZERO POSITION CONTROL.

**NOTE**

Plexiglas material is electrically non-conductive. An internally-grounded transducer should be used. If an internally-grounded transducer is not available, place a piece of aluminum foil between the transducer and plexiglas disc. Use a couplant on both sides of the foil.

4-58. CHECKING THE DEAD ZONE. The dead zone is the length of the sound path following entrance of the sound beam into the material, during which no reflection can be observed because of obstruction by the transmitting pulse. A dead zone is inherent in all ultrasonic test equipment. The use of good transducers and the proper electronic circuit will minimize the length of the dead zone to a great extent. In some types of instruments an extensive dead zone is not too obvious as the length of the transmitting pulse is electronically suppressed. The sensitivity indication immediately after sharp transmitting is reduced to practically zero and reflections are not visible. The dead zone should not be determined by measuring the width of the transmitting pulse alone, but by a practical test. This test can be performed with the International Institute of Welding reference block with the transducer placed in positions as indicated in Figure 4-25.

4-59. CHECKING RESOLUTION. Resolution is the ability of ultrasonic equipment and transducers to discriminate between two or more reflecting surfaces which lie at slightly varying depths. Discrimination is necessary between a defect and the weld bead as illustrated in Figure 4-26. The resolution is checked by placing the transducer in the position illustrated in Figure 4-27. Three different sound paths are shown. The reflections from these surfaces should be separate and distinct at frequencies of 2.25 and higher.

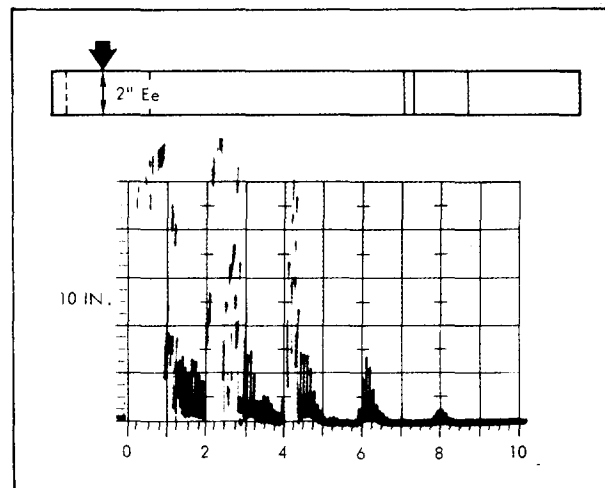


Figure 4-24. Positioning Transducer for Checking Longitudinal Waves - Range 5 Inches to 10 Inches at Lower Frequencies



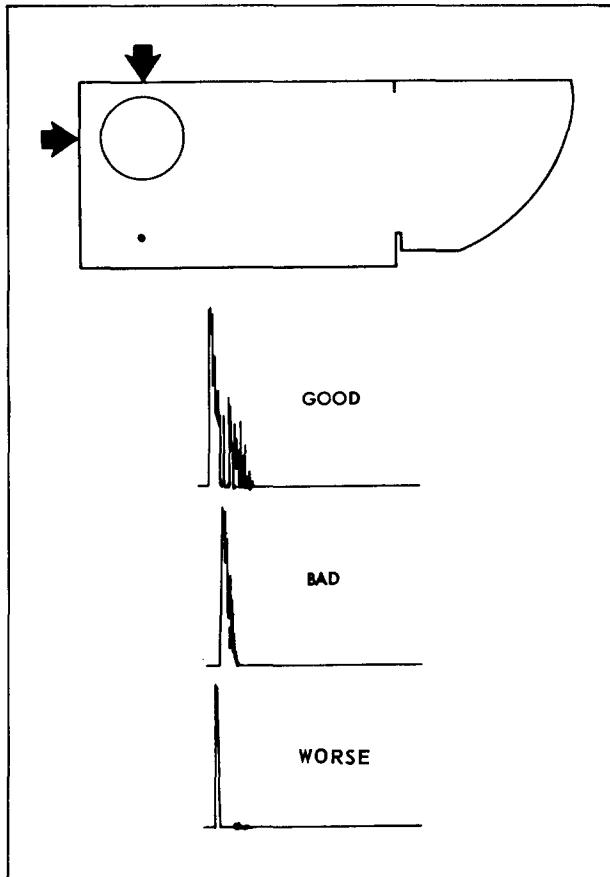


Figure 4-25. Positioning Transducer for Checking Dead Zone

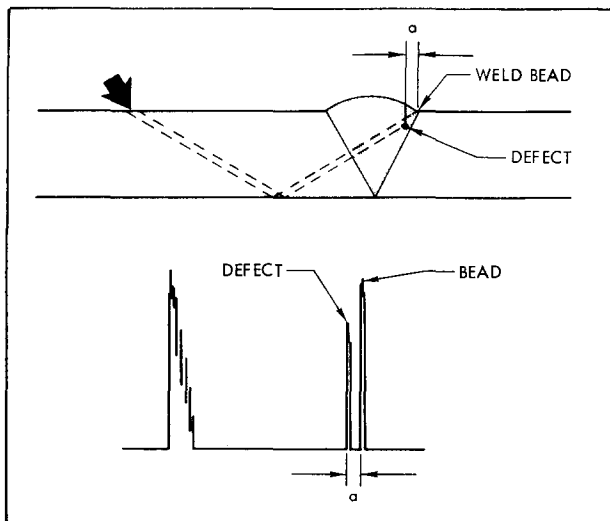


Figure 4-26. Discrimination Between a Defect and Weld Bead

#### 4-60. STANDARDIZING FOR TRANSVERSE WAVE INSPECTION.

4-61. GENERAL. As the velocity of transverse waves is approximately one-half of longitudinal waves, a complete change in the calibration of the equipment is required. The change of equipment is augmented by the fact that an inspection with transverse waves is performed without the benefit of a back reflection as in inspecting welds. The International Institute of Welding reference block has been designed primarily for calibrating transverse waves. To calibrate for transverse wave inspection, proceed as follows:

a. Place a normal (longitudinal) transducer in position as illustrated in Figure 4-28.

b. Use a range of 10 inches. The result is a sound path 3.64 inches long for longitudinal waves which is equivalent to a sound path of 2 inches for shear waves.

#### SOUND PATH COMPUTATION IN STEEL

$$C_L = 6000 \text{ M/sec}$$

$$C_t = 3300 \text{ M/sec}$$

$$\text{Thus } \frac{6000 \text{ M/sec}}{3300 \text{ M/sec}} = \frac{x}{2 \text{ inches}} \therefore x = 3.64 \text{ inches}$$

c. Adjust the equipment so that the first, second, and third reflections, etc., occur at the 2-inch, 4-inch, 6-inch marks, etc., respectively.

d. Adjust the reflections with their respective marks, using the FINE RANGE CONTROL and ZERO POSITION CONTROL.

e. Exchange the normal transducer for the proper angle transducer.

f. Position the angle transducer as illustrated in Figure 4-29 and move the transducer until a reflection of maximum amplitude is received.

g. As the length of the sound path in the reference block is 4 inches, the reflection from the arc should occur at the 4-inch mark. However, the reflection from the arc will occur between the 4-inch and 5-inch mark because the sound path passes through the plexiglas wedge of the angle transducer.

h. Move the screen pattern with the ZERO POSITION CONTROL only, to the left so the reflection from the arc is exactly at the 4-inch mark. (See Figure 4-30).

#### NOTE

The sound path in the plexiglas wedge is now in front of the zero point and the screen pattern represents the sound path in the reference block.

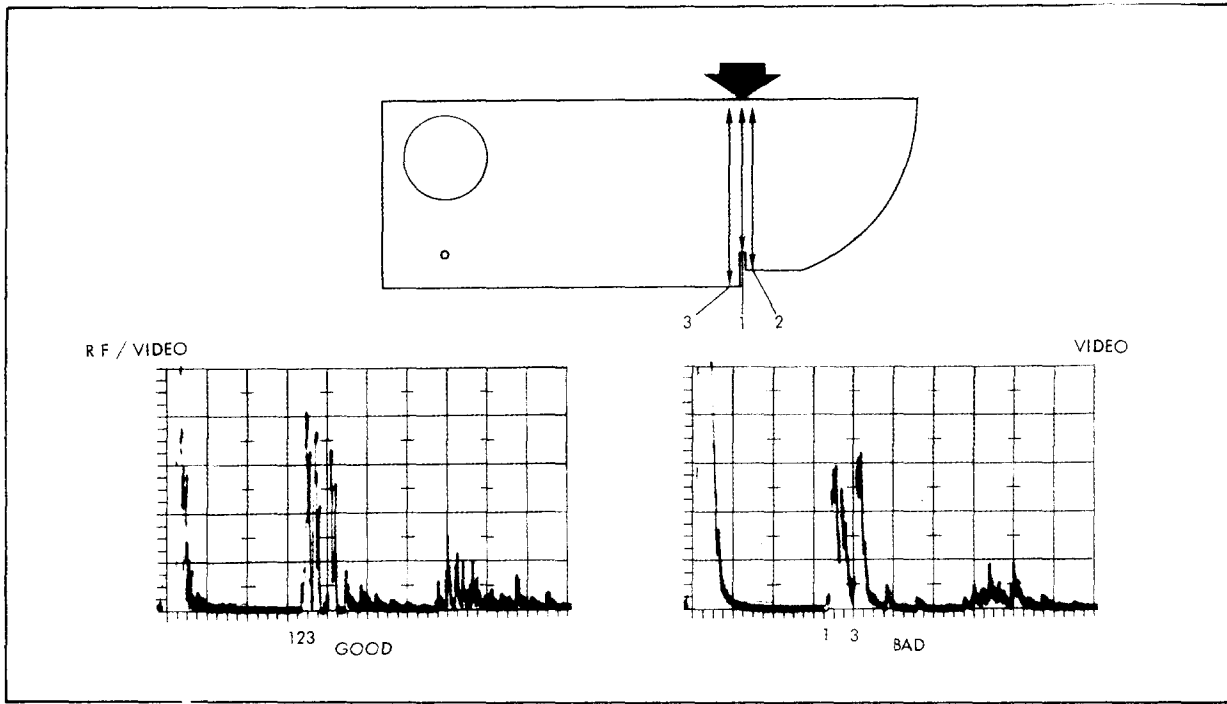


Figure 4-27. Resolution Test on Reference Block

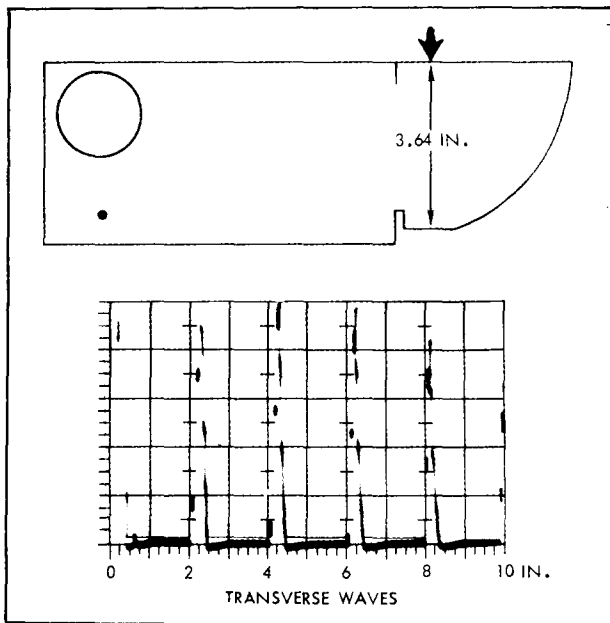


Figure 4-28. Positioning Longitudinal Transducer for Standardizing Transverse Waves

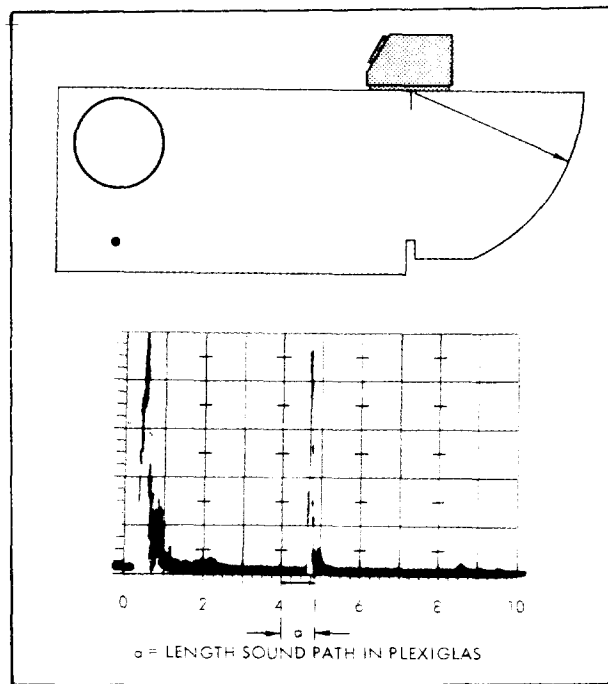


Figure 4-29. Positioning Angle Transducer to Determine Point of Incidence

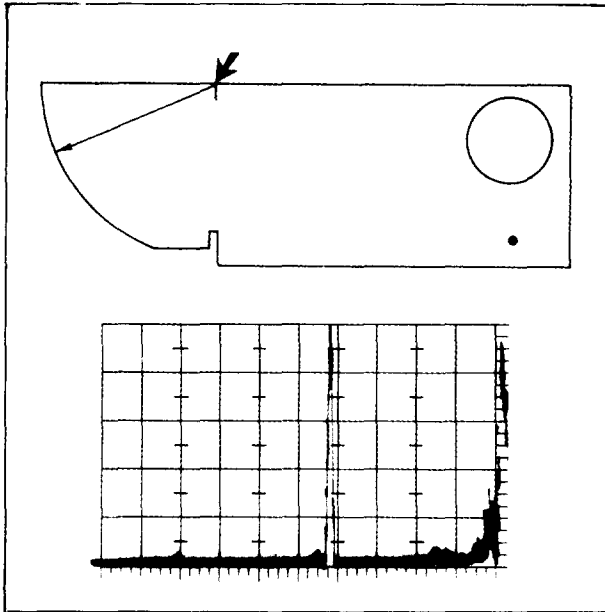


Figure 4-30. Correcting Sound Path for Plexiglas Wedge

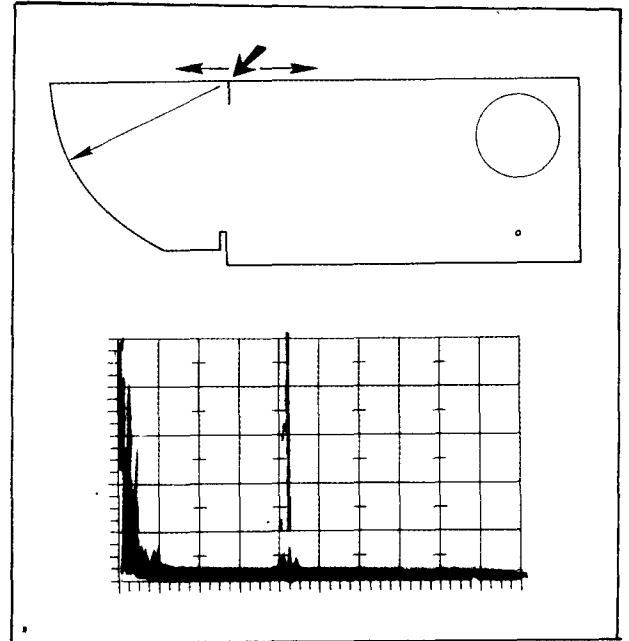


Figure 4-32. Checking Point of Incidence of an Angle Transducer

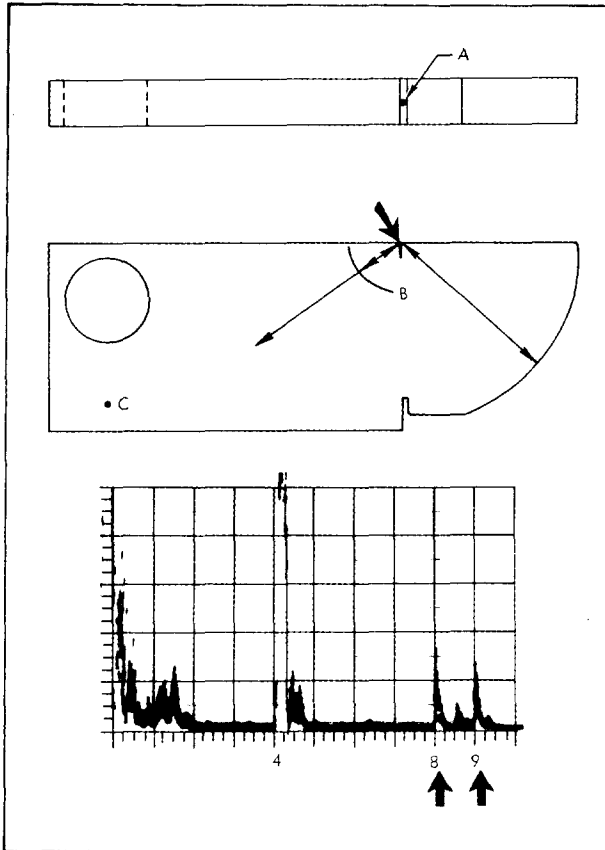


Figure 4-31. Adjusting Linearity at 8 and 9 Inches

i. Increase the sensitivity until two more reflections are obtained occurring at approximately the 8 inch and 9-inch marks, as shown in figure 4-31. These 2 reflections are caused by the hole "A" and the groove "B" in the IIW block. When the sound-beam enters the reference block at the exact center of the arc, it gives a reflection from the arc at 4 inches. If there was no hole, the sound energy that did not cross the interface between reference block and transducer would reflect from the interface and not come back to the transducer again. Hole "A", however, will reflect part of the sound energy back to the arc and thus cause a reflection at 8 inches. The groove "B" with the same center as the arc, but 1 inch away, will also reflect some of this sound energy back to the arc, but as the sound path is 1 inch longer it will give a reflection at the 9-inch mark. Do not confuse hole "A" with hole "C" which is used for sensitivity standardization only.

j. The equipment is now standardized for shear waves using a specific angle transducer.

k. If another angle transducer is used, repeat steps h through j. Repeating these steps for each angle transducer is required because the length of the sound path in the plexiglas wedge varies for each angle and with different manufacturers of transducers.

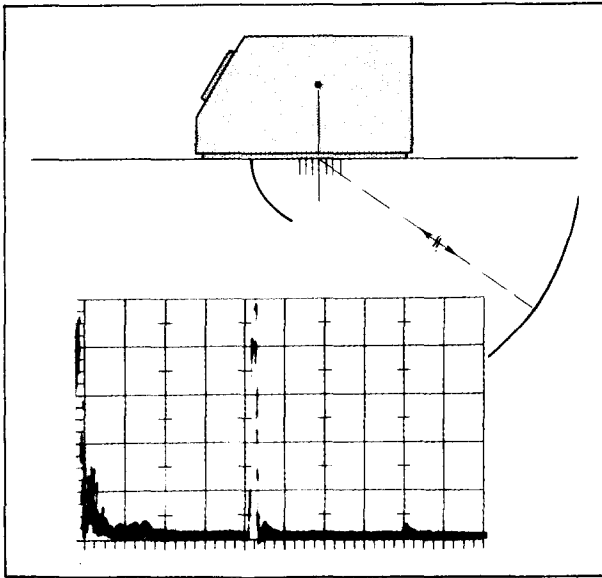


Figure 4-33. Check for Angle of Incidence

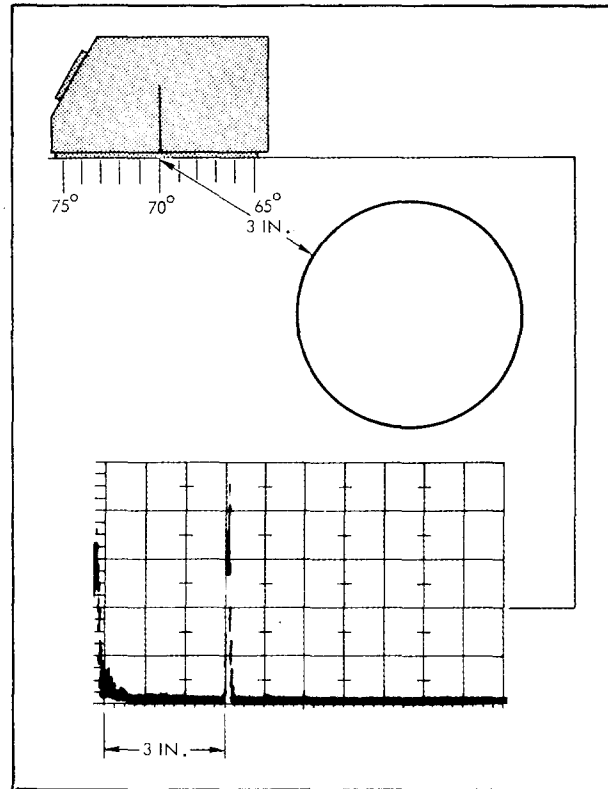


Figure 4-35. Checking for Angle of Refraction

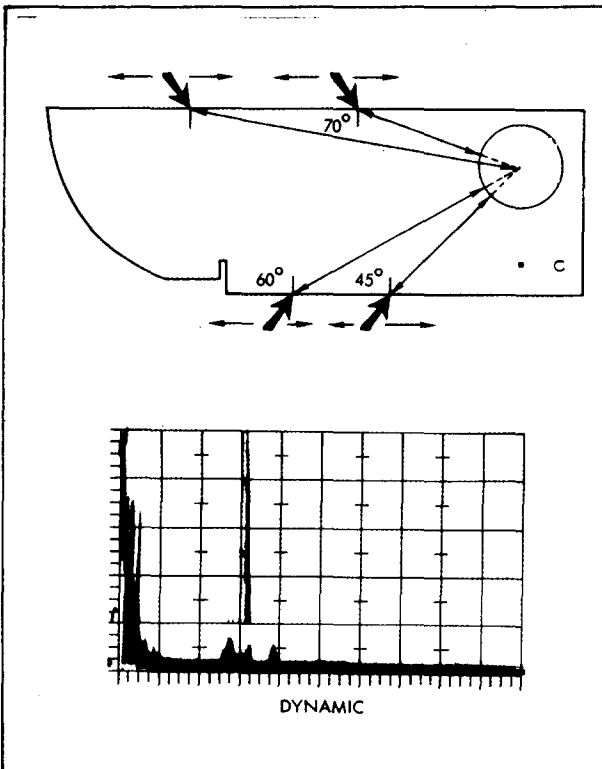


Figure 4-34. 70° Angle Presentation of Angle of Refraction

4-62. ANGLE TRANSDUCERS.

4-63. Checking Point of Incidence and Angle of Refraction. The point of incidence and the angle of refraction must be known to perform accurate ultrasonic inspection. Both the point of incidence and the angle of the refraction for a specific material should be indicated on the transducer. Transducer performance varies with its usage and a check should be made to determine point of incidence and angle of refraction used. When angle transducers are used, which do not indicate the point of incidence, the following check is mandatory.

- a. Position the angle transducer as illustrated in Figure 4-32.
- b. Move the transducer until a maximum reflection from the arc is obtained.
- c. Mark the angle transducer at the point on the reference block where the center of the arc is indicated. The mark indicates the point of incidence and is the location of the center of the sound beam. (See Figure 4-33).
- d. Place the angle transducer on the position marked on the reference block for the proper angle of the transducer.
- e. Move the transducer until a maximum reflection from the 2-inch diameter hole is obtained. (See Figure 4-34).

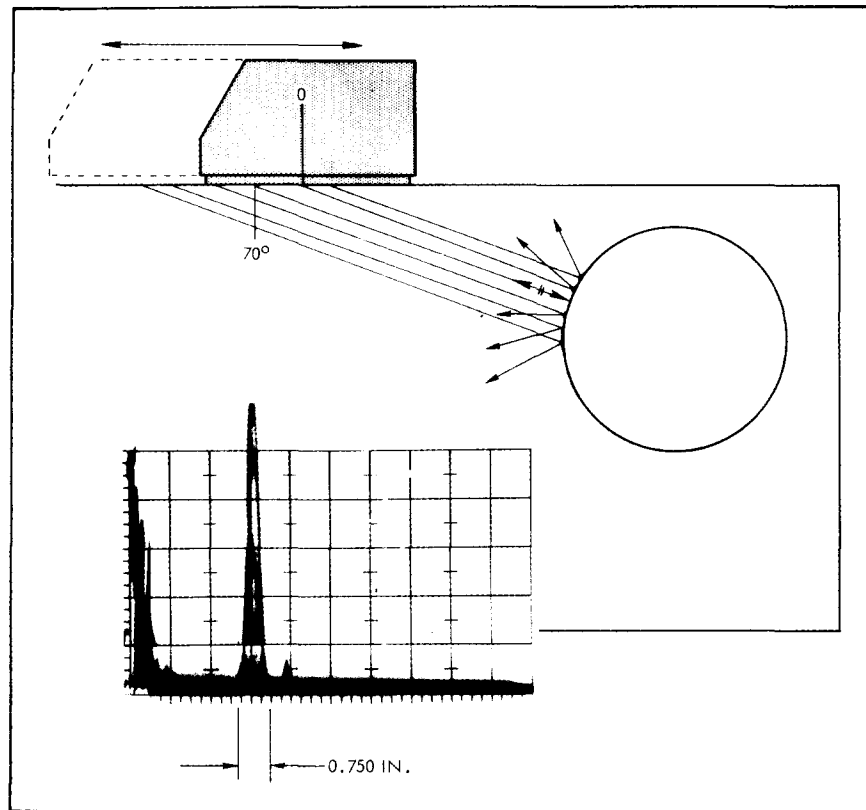


Figure 4-36. Measurement of Beam Characteristics

f. The angle appearing on the reference block at the point of incidence mark on the transducer is the angle of the transducer. (See Figure 4-35).

4-64. Beam characteristics are measured in the same manner as the angle of refraction is measured. In measuring beam characteristics, the transducer is positioned until a maximum reflection of the 2-inch hole is obtained. The maximum reflection indication is termed the beam axis. The beam spread is derived from the curve of all reflections obtained during positioning of the transducer for minimum, through maximum, and back to minimum, as illustrated in Figure 4-36.

4-65. SENSITIVITY ADJUSTMENT. The sensitivity required for a specific inspection is determined by preliminary testing such as an indication of defects on a radiograph; a comparison with artificial defects, such as holes or notches of a known reflecting area or destructive testing. The particular setting of the instrument is noted and the reference block is used as a tool for resetting this sensitivity. The sensitivity is then stated as the amplitude in inches or scale divisions of the reflection resulting from the 0.060-inch hole at a specific distance in inches. The specific distances for each angle are illustrated in Figure 4-37. For the 2-inch diameter hole, the

plexiglas disc or the arc can all be used as reference points depending on the sensitivity used. In all cases the actual reflecting surface and the length of the sound path must be stated.

4-66. During inspection of fillet welds or similar constructions a sensitivity adjustment is required for longitudinal waves when a back reflection cannot be obtained. Figure 4-37 illustrates the reference setting on the reference block. The transducer is placed as shown in Figure 4-37 and moved until a maximum reflection from the reflection surface (in this case the 0.060-inch hole "C") is obtained. The amplitude of this reflection is taken as the relative value for the sensitivity and makes it necessary that the acoustical properties of all reference blocks be the same. This is accomplished by measuring the damping properties of the material.

4-67. During inspection of butt welds or similar parts, a sensitivity adjustment is required for transverse waves as a back reflection cannot be obtained in most cases. For low sensitivity settings either the arc or the 2-inch diameter hole serve as a reference point for the sensitivity setting. For higher sensitivity settings the 0.060-inch hole in the reference block serves as the reference point. The transducer is placed as illustrated in Figure 4-38 and moved until a maximum reflection from the hole is obtained. The position of the transducer, the amplitude of the

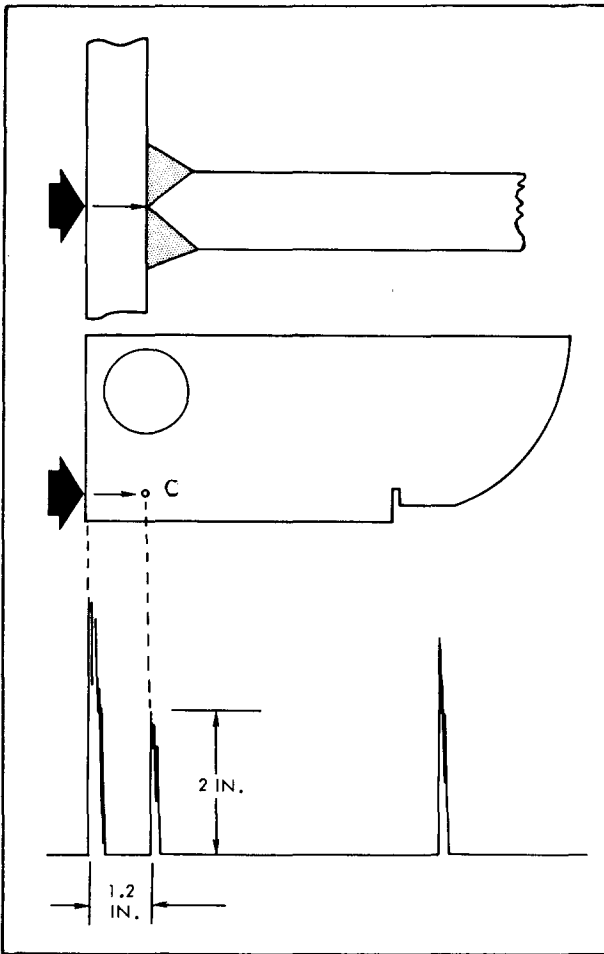


Figure 4-37. Adjustment for Sensitivity on Reference Point

reflection and its exact position in the screen pattern is noted after adjustment of range and zero point correction is made. When inspecting welds in materials of more than 1 inch thick, the transducer is placed in the position as illustrated in Figure 4-39. In this case a soundpath of 6.4 inches in steel is obtained at 45 degrees before reflection occurs from the reference point. Accuracy in measuring is necessary to determine the reflection from the reference point. The length of the sound path should first be physically measured on the reference block in order to obtain the necessary accuracy.

**4-68. INSPECTION METHODS AND SCREEN PRESENTATION.**

4-69. Depending upon the application, non-destructive inspection with pulse-echo equipment is performed by using several methods. Inspection either by immersion in liquids or by direct contact may be made. Corresponding to the cathode-ray tube presentation, three divisions of inspection are used; direct inspection, indirect inspection, and semi-direct inspection. A separate adjustment of the equipment is required for each method.

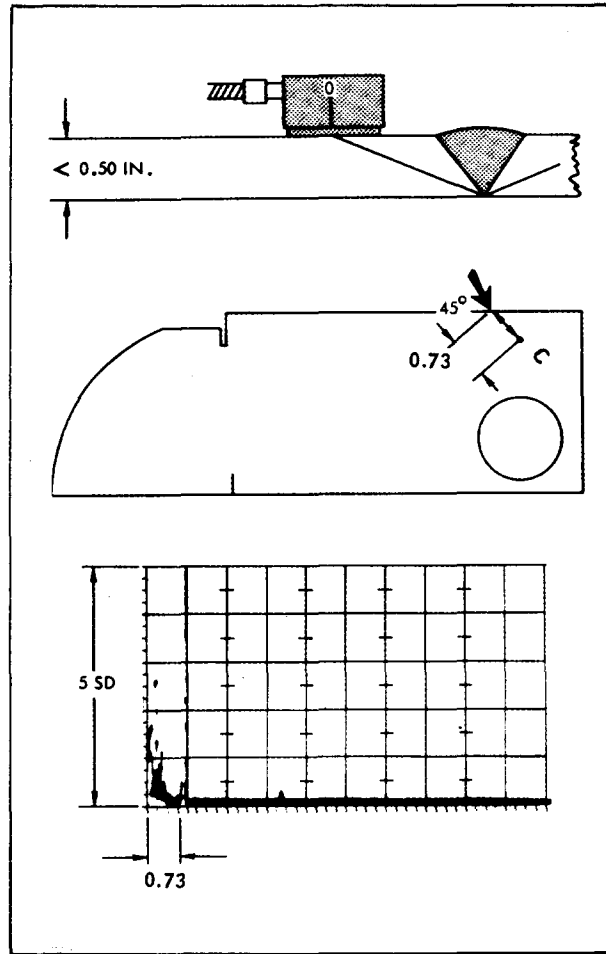


Figure 4-38. Adjustment for Sensitivity on Reference Point - Transverse Waves at Short Range

**4-70. DIRECT METHODS OF INSPECTION.**

4-71. Single and Double Transducer Reflection Method. By using either a single or double transducer method of inspection, the defect in the inspected part is directly located and a comparison is made between the amplitudes of the defect and the back reflection. The approximate size of the defect in the inspected part is determined by the ratio of the amplitudes of the defect and the back reflection. (See Figure 4-40).

4-72. High Range Reflection Method. A number of multiple back reflections will occur when range is increased. Certain defects will not give an immediate indication but will give a reflection after the first back reflection, which is caused by interference in the near zone. (See Figure 4-41).

**4-73. INDIRECT METHODS OF INSPECTION.**

4-74. Shadow Method. The shadow method of inspection is used when it is expected that large defects will appear in coarse-structured parts such as castings. The transmitted sound will be completely or partially

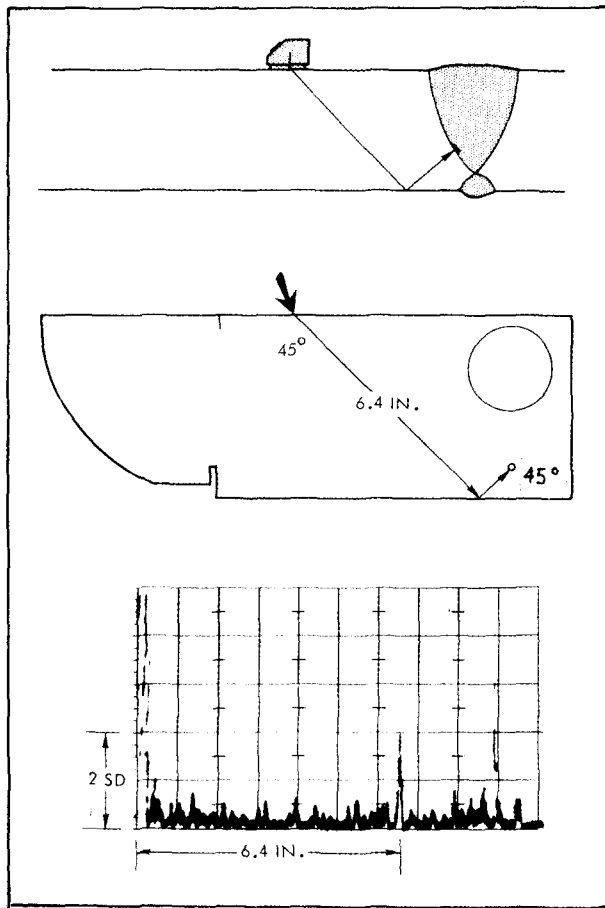


Figure 4-39. Adjustment for Sensitivity on Reference Point - Transverse Waves at High Range and High Sensitivity

interrupted by the defect so that the amplitude of the back reflection is decreased or completely eliminated. The shadow method of inspection is performed by placing two transducers opposite each other or on the same surface beside each other. When thin parts are to be inspected, the transducers should be mounted at a slight angle to receive a direct reflection from the transmitter to the receiver. A single transducer is simpler to use in this case. (See Figure 4-42.)

4-75. Absorption Method. The absorption-method of inspection is used to determine small flaws in the inspected part. The equipment must be adjusted for a high range. The regularity of the multiple back reflections and the total energy received are a relative measure of soundness of the material. Either single or separate transducers may be used when inspecting by the absorption method. (See Figure 4-43.)

4-76. Attenuation Method. The attenuation method of inspection is used to obtain information regarding the structure of the part. The ratio of amplitudes of the multiple back reflections is a relative measure of the structure as illustrated in Figure 4-44. A curve can be drawn across the tops of these reflections which gives a relative value for the grain size, provided the inspected part is homogeneous.

4-77. Ultra-High Range Shadow Method. Contrary to the normal shadow method of inspection where only the first back reflection can be observed, the ultra-high range shadow method makes use of combined back reflections. The main difference between the normal shadow method and the ultra-high range shadow method is that in the ultra-high range shadow method only the total energy received and not the regularity of the indications is considered. All reflections are compressed into one indication. The ultra-high range shadow method of inspection is used for inspecting thin-walled cast materials. (See Figure 4-45).

4-78. SEMI-DIRECT METHOD. The semi-direct method of inspection is a combination of direct and indirect methods of inspection. In addition to observing change in back reflection and the regularity of the pattern in the semi-direct method, the appearance of the defect indications is also considered.

4-79. SPECIAL METHODS. When irregularly shaped parts are being inspected, it is often impossible to receive a back reflection. The reflection method is used without a back reflection under these circumstances. The transducer must first be placed at a point where a back reflection is obtainable. The equipment is then adjusted and inspection performed. Care must be exercised with respect to the couplant. Due to lack of back reflection, it is not possible to check this method of inspection. Immersed scanning is preferred in these cases.

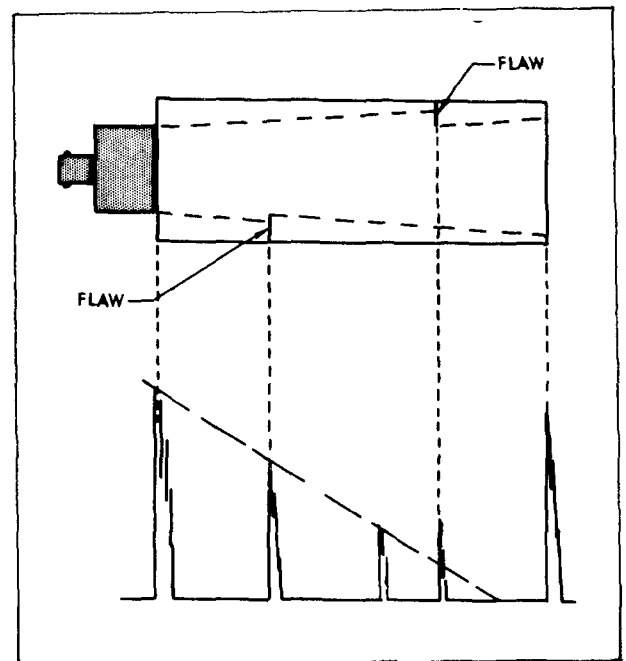


Figure 4-40. Direct Reflection Method of Inspection

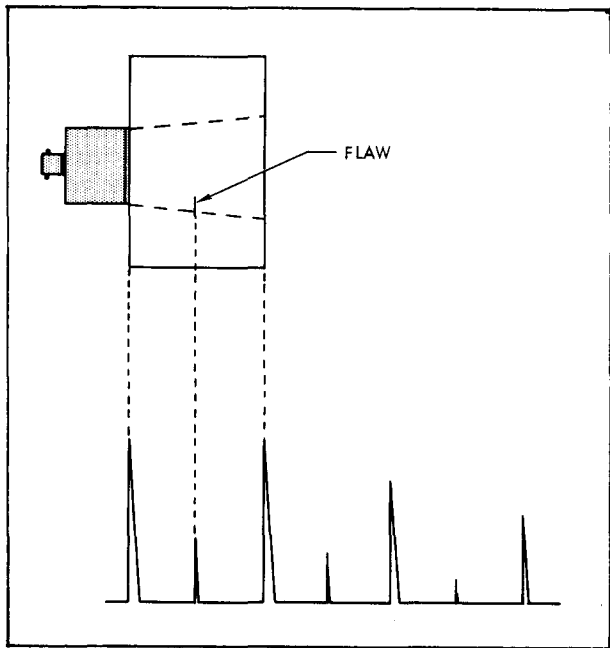


Figure 4-41. High Range Reflection Method of Inspection

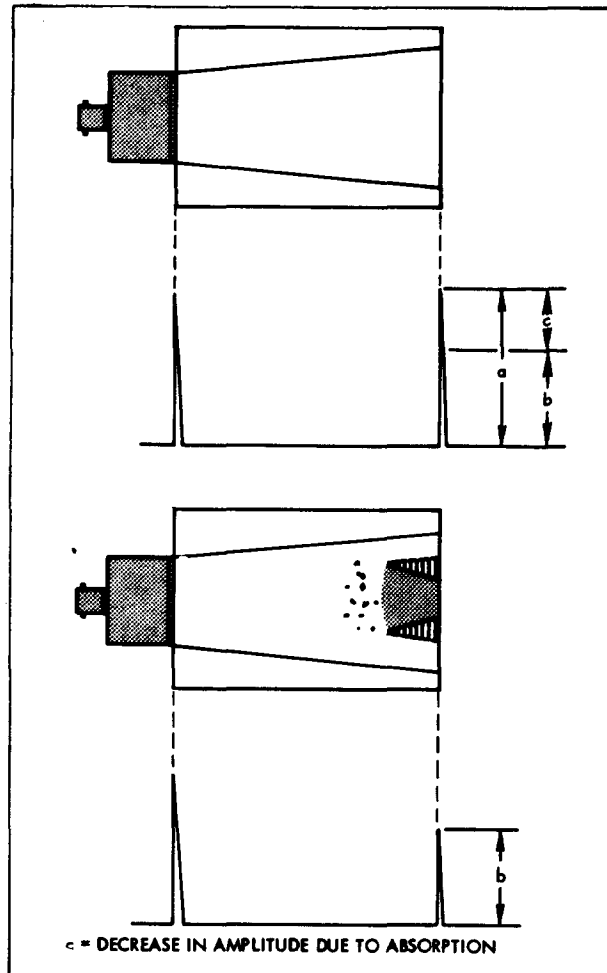


Figure 4-42. Shadow Method of Inspection

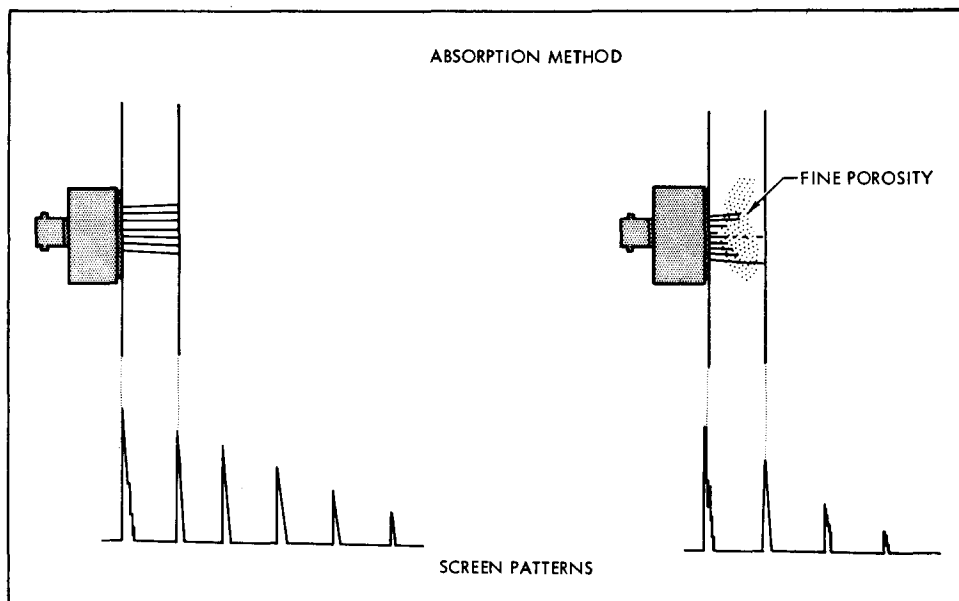


Figure 4-43. Absorption Method of Inspection



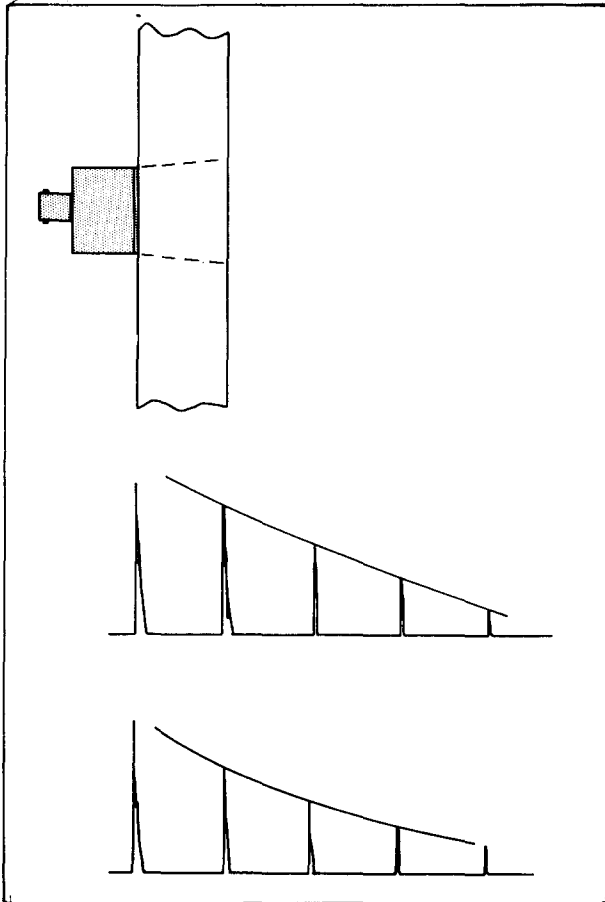


Figure 4-44. Attenuation Method of Inspection

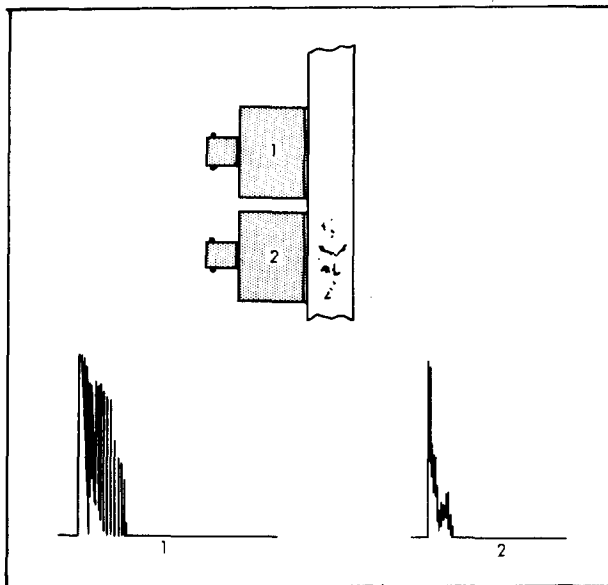


Figure 4-45. Ultra-High Range of Shadow Method of Inspection

4-80. **SURFACE PREPARATION.** The surfaces of a part to be inspected should be smooth and free of scale, loose paint, or other residue. Painted surfaces are inspected without difficulty provided the layer of paint is thin and has a good bond with the part under inspection. Surface irregularities of welded parts should be removed when the irregularities are in the path of the ultrasonic transducer.

**4-81. THEORETICAL AND PRACTICAL ASPECTS OF ULTRASONIC WELD INSPECTION.**

4-82. For ultrasonic weld inspection only angle transducers are used except for fillet welds. The sound beam is transmitted through the parent metal and into the weld. The parent metal therefore, should be free of defects if the sound beam is to pass through the metal readily. Freedom from defects in the parent metal is determined by inspecting an area three inches to six inches on both sides of the weld. Inspection is made for laminar-type defects in the parent metal by using a normal transducer with a frequency of 2.25 or 5 megacycles. The approximate extent of the inspected area depends upon the thickness of the parent metal. Figure 4-46 shows thickness of parent metal and extent of inspected area:

THICKNESS OF PARENT METAL	EXTENT OF WELD INSPECTION AREA
Less than 1/2 inch	Inspect area up to 3 inches on both sides of weld
1/2 inch to 1 inch	Inspect area up to 4 inches on both sides of weld
1 inch to 2-1/2 inches	Inspect area up to 5 inches on both sides of weld
Over 2-1/2 inches	Inspect area up to 6 inches on both sides of weld

Figure 4-46. Inspecting Parent Metal in Weld Area to Locate Defects

4-83. Angles with respect to normal use in weld inspection of steel are 35-, 45-, 60-, 70-, and 80-degree angles. Frequency used is 2.25 megacycles for regular angle transducers and a frequency of 5 megacycles is used for miniature angle transducers. Figure 4-47 shows the transducer angle used in relation to plate thickness of the parent metal which should be used as a guide only. Figure 4-48 shows angles used for steel with respect to normal.

ANGLE TRANSDUCER USED	PLATE THICKNESS
70 or 80 degree	Up to 1/2 inch thick
60 to 70 degree	Up to 1 1/2 inches thick
45 or 60 degree	Up to 2 1/2 inches thick
45 degree	Over 2 1/2 inches thick

Figure 4-47. Comparison of Angle Transducer and Plate Thickness

4-84. The relationship between the angle transducer used to inspect the weld and the shape of the weld is of great importance. Where a critical area is in the center of the weld such as an "X" weld, the weld should be inspected with an angle transducer for one-half plate thickness. (See figure 4-49). The optimum angle to detect lack of weld fusion is the complement angle of the weld opening as indicated in Figure 4-50. Welds in heavy plate thicknesses may have to be inspected in tandem with the transmitter placed near the weld as illustrated in Figure 4-51. A calculator, as described in paragraph 4-91 is used to determine factors described in paragraphs 4-82 and 4-83.

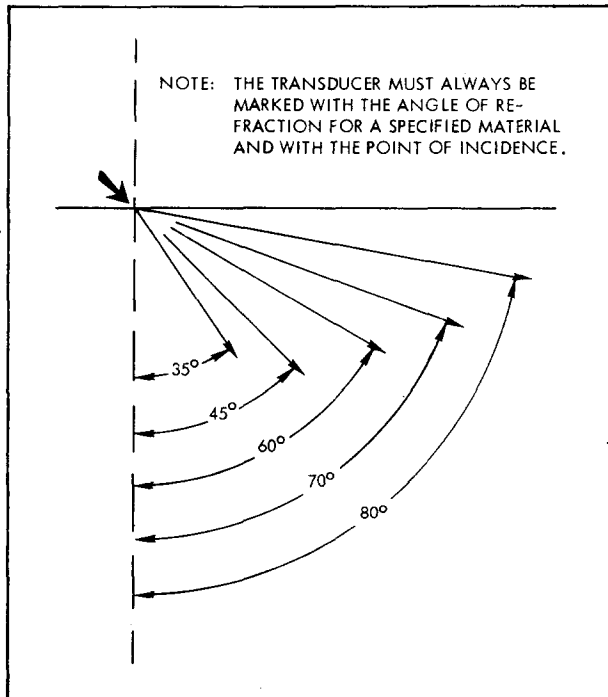


Figure 4-48. Angles of Refraction for Steel with Respect to Normal

4-85. The exact location of a reflecting surface in a weld is necessary to determine the location and relative size of the defect. The sound path can be determined mathematically as illustrated in Figure 4-52 and as follows for a full skip "P" of the sound path.

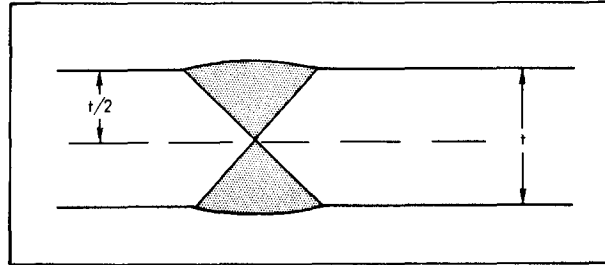


Figure 4-49. Transducer Choice for One-Half Plate Thickness

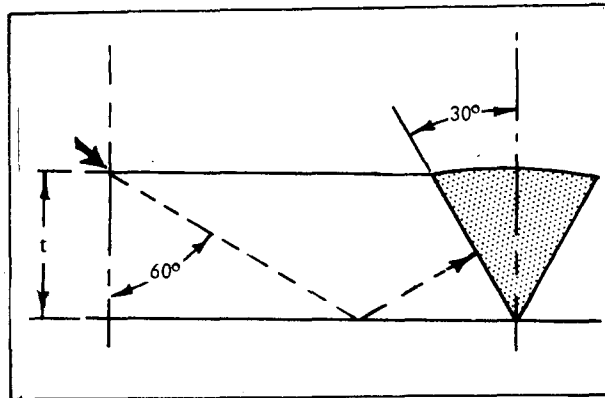


Figure 4-50. Optimum Angle Used in Detecting Lack of Fusion

- Where:
- I = Point of incidence
  - t = Plate thickness
  - s = Sound path for full skip distance
  - P = Full skip distance on surface

Since  $\alpha$  and t are known factors, both s/2 and P/2 can be determined:

$$S/2 = \frac{t}{\cos \alpha}$$

$$P/2 = S/2 \sin \alpha$$

4-86. When the sound path exceeds s/2 calculations can be determined by using the mirror image as illustrated in figure 4-53 and as shown in this example:

- Stated: 1) Angle of refraction 60 degrees  
 2) Distance from point of incidence to center of weld 4.625 inches (on surface)  
 3) Distance from point of incidence to defect 5.5 inches (sound beam path)

- Determine: 1) Location of defect with respect to center of weld  
 2) Depth of defect under surface

Solution:  $a = c \times \sin 60^\circ = 5.5 \times 0.866 = 4.76$  inches  
 $b = c \times \cos 60^\circ = 5.5 \times 0.500 = 2.75$  inches

Location from center of weld  $4.76 - 4.625 = 0.135$  inch away from transducer.

Depth under surface  $= 2t - b = 4.0 - 2.75 = 1.25$  inches or the depth under the surface  
 $AB = FE = 2.0$  inches  
 $AC = \frac{AB}{\cos 60^\circ} = \frac{2.0}{0.5} = 4.0''$   
 $AC + CD = 5.5''$   
 $CD = 5.5'' - 4.0'' = 1.5''$

(Identities from the Mirror Image)

$CX = CD$ ;  $LXCE = LDCE = 30^\circ$ ;  $DE = EX$   
 $EX = (\sin 30^\circ) (CX) - (0.5) (1.5'') = 0.75''$   
 $FX = FE - EX = 2.00'' - 0.75'' = 1.25''$

4-87. Calculations described in paragraph 4-86 are too involved for proper application in field work. The use of a direct-reading calculator is required for ultrasonic inspection as described in paragraph 4-91.

4-88. **ULTRASONIC INSPECTION OF WELDS.** Examples for the inspection of welds by ultrasonic techniques are given in the following step-by-step procedures and must be performed in sequence as shown:

- a. Connect 5mc transducer (longitudinal) with the proper cable to the ultrasonic instrument (only equipment fulfilling the requirements outlined in paragraph 4-36).

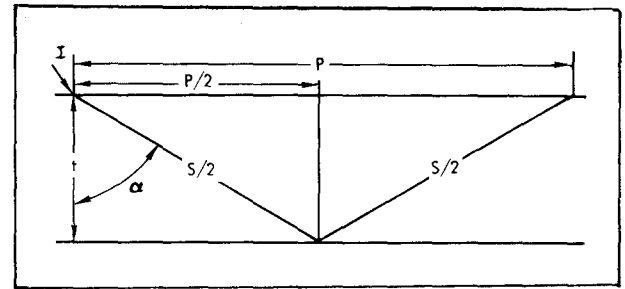


Figure 4-52. Sketch for Determining Sound Path

- b. Connect the ultrasonic instrument to the proper power source.  
 c. Allow for stabilization time as indicated by manufacturer.  
 d. Adjust ultrasonic instrument for 10-inch soundpath for transverse waves utilizing an ultrasonic reference block.

4-89. **PROCEDURE FOR USING INTERNATIONAL INSTITUTE OF WELDING ULTRASONIC REFERENCE BLOCK.**

- a. Place 5mc transducer (longitudinal) on the reference block as shown in Figure 4-54.  
 b. Adjust pattern with FINE RANGE CONTROL so that 5 reflections occur equally spaced across the cathode-ray tube. (See figure 4-54.)  
 c. Connect proper angle transducer to the coaxial cable and place the angle transducer on the reference block in the position as shown in figure 4-55.  
 d. Adjust the pattern with the HORIZONTAL POSITION CONTROL in such a way that the reflection from the arc occurs exactly at the 4-inch mark. (See Figure 4-55).  
 e. Increase the SENSITIVITY to such a level that the reflections from the 0.060-inch hole and from the 90-degree groove can be recognized. These reflections should occur at the 8- and 9-inch mark. Readjust with FINE RANGE CONTROL if necessary. (See figure 4-56, cross reference paragraph 4-61.)

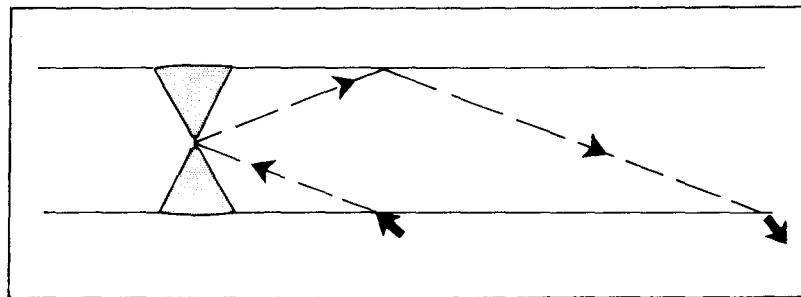


Figure 4-51. Tandem Inspection of Welds

f. Place angle transducer in the position as illustrated in figure 4-57 and move the angle transducer until a maximum reflection from the hole is obtained.

g. Adjust the SENSITIVITY so that the amplitude of the reflection is exactly as given in the specification.

4-90. DETERMINING WITH VISUAL AID SOUND PATH IN THE MATERIAL. The visual aid method is based on the calculation given in paragraphs 4-85 and 4-86.

a. Sketch a cross section on graph paper of the material showing the weld.

b. Draw the sound path in the cross section depicting it as a zig-zag line. Use the exact angle as indicated on the transducer.

c. Mark the sound path in 0.5-inch divisions or smaller if necessary. When a reflection occurs on the oscilloscope pattern make a note of the distance from the point of incidence to the center of the weld and the length of the sound path.

d. Mark the center of the weld on the graph and sketch the outline of the weld around it. Mark the length of the sound path on the zig-zag line. The location of the defect is now determined with respect to the weld and its depth under the surface and position with respect to the center of the weld. The use of a special calculator will enable the inspector to perform this task with ease and speed.

4-91. DIRECT READING ULTRASONIC CALCULATOR CARD. The direct reading calculator card is used to determine factors necessary for ultrasonic weld inspection when two factors are known:

- a. Plate thickness of inspected part.
- b. Angle of transducer used.

4-92. The calculator card consists of three parts. (See Figure 4-58).

a. A card having a grid scale division along both the x and y axes and an arc illustrating increments from 35 to 90 degrees with respect to normal.

b. A transparent slide card holder which can be slipped over the calculator card and on which a sketch of the weld can be made.

c. A ruler attached to the transparent slide for drawing lines.

**NOTE**

The reverse side of the calculator card provides space for recording information of the inspected part.

4-93. CALCULATOR USE. The use of the calculator is explained in the following examples:

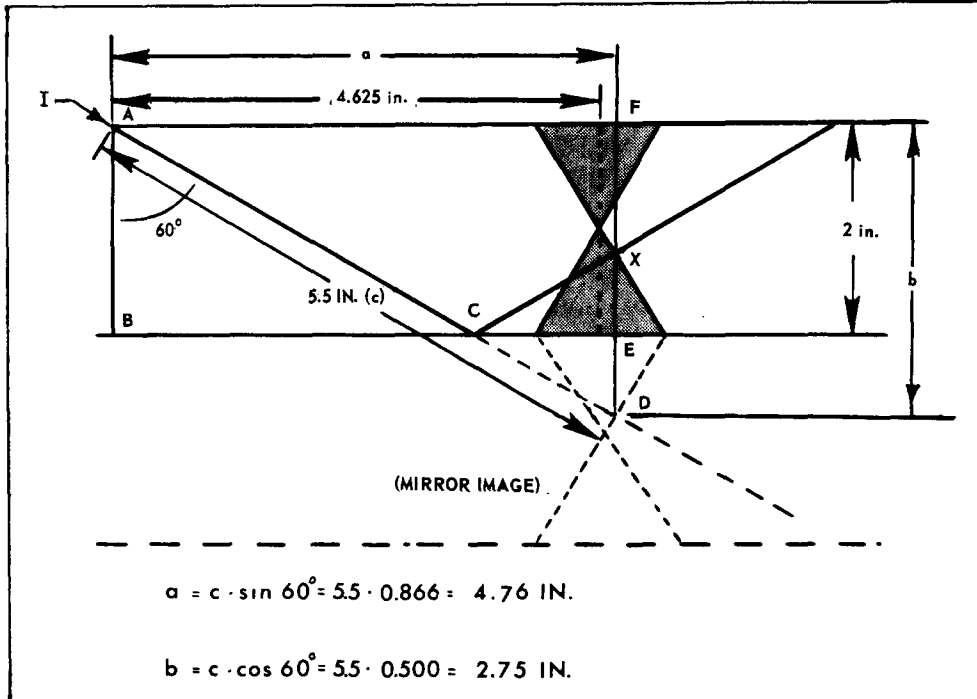


Figure 4-53. Calculation of Defect Location Using Mirror Image of Weld

Figure 4-59 (Example A)

GIVEN

Material	Steel
Thickness	2 inches
Angle of transducer	60 degrees Fe.
Weld	X - opening 30 degrees

a. Sketch sound path from "Point of Incidence (i) through the 60 degree mark to the horizontal line at 2 inches (point A). This is half the skip distance as measured on the surface, 3-7/16 inch (approximately). For full skip distance double this distance (2 x 3-7/16 inches) and mark that point at 6-7/8 inches (approximately) with point B. Draw line from point A to point B, thus completing a full skip. Mark the line depicting the sound path in inches with ruler. Sketch weld on plastic slide with engraved line as exact center. Slip calculator card into plastic slide.

b. A defect reflection occurs at 5.5 inches, with the point of incidence on the transducer at 4-5/8 inches from center of the weld.

c. Adjust centerline on plastic slide over 4-5/8 inch mark. Defect reflection occurs in the weld at 5.5 inches, that is 1 1/4 inches under the surface, 1/8 inch from center weld on the far side of the transducer.

d. By moving the transducer while scanning the same weld a defect reflection occurs at 2 inches with the point of incidence on the transducer 1 3/4 inch from the center of the weld (See figure 4-59, Example B).

e. Follow procedures according to subparagraph c. Defect occurs approximately 1 inch under surface in the center of the weld.

Figure 4-59 (Example C)

GIVEN

Thickness	1 inch
Angle of transducer	70 degrees Fe.
Weld shape	V with 30 degree opening

f. Sketch sound path and weld according to subparagraph a for 1 inch material and 70 degree angle.

g. A defect reflection occurs at 2-5/16 inch with the point of incidence on the transducer 2-3/4 inch from the center of the weld. (See figure 4-59, Example C.)

h. Follow procedures according to subparagraph c. Defect occurs 1 inch under the surface in center of weld.

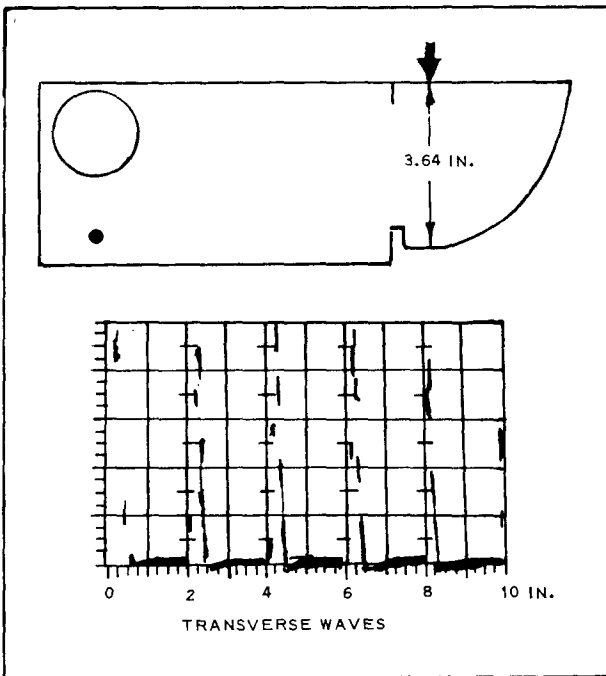


Figure 4-54. Checking Transverse Waves with Longitudinal Transducer

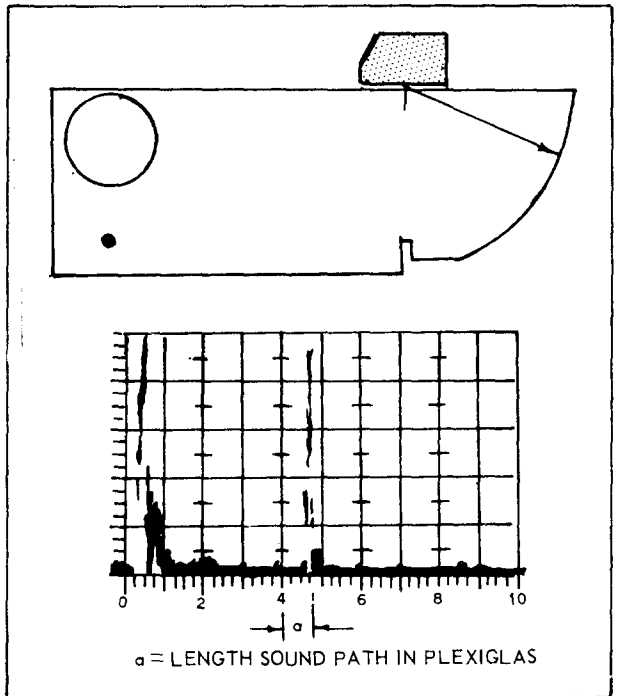


Figure 4-55. Checking Transverse Waves at 4 Inches

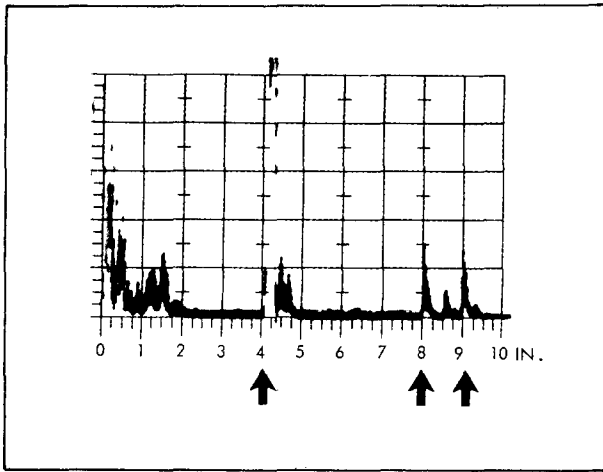


Figure 4-56. Checking for Transverse Waves at Higher Sensitivity to Obtain Reflections at 4 Inches, 8 Inches, and 9 Inches

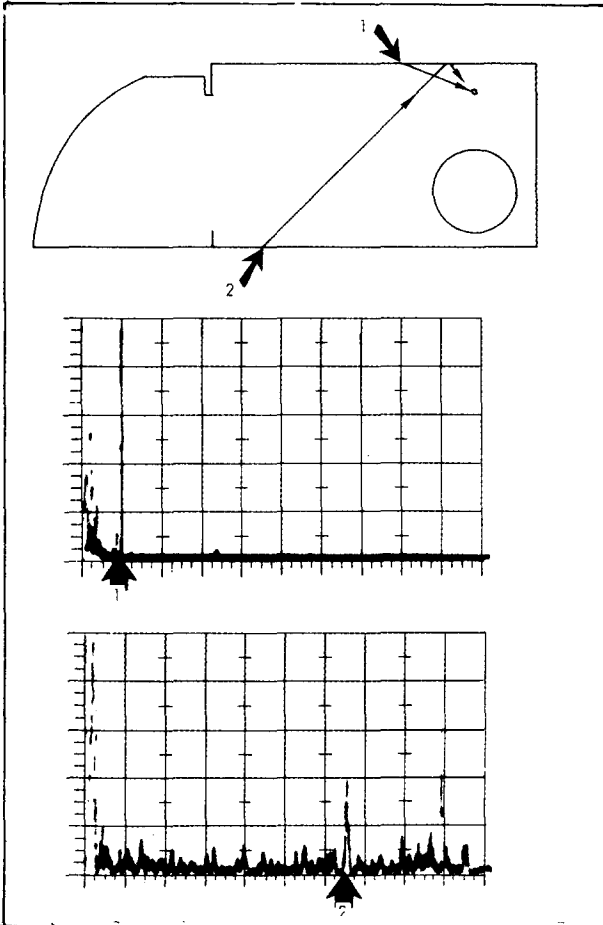


Figure 4-57. Checking Sensitivity

1. By moving the transducer while scanning the same weld a defect reflection occurs at 3-3/4 inches with the point of incidence on the transducer at 3-3/4 inches from the center of the weld (See figure 4-59, Example D.)

j. Follow procedures according to subparagraph c. Defect occurs approximately 5/8 inch under the surface approximately 1/4 inch from the center of the weld on the transducer side.

4-94. The direct reading calculator will indicate the following:

a. The extent of movement of the transducer in scanning the whole weld.

b. Determine in advance the proper angle and location of the transducer by using the calculator in reverse.

c. To report information by sketching the cross-sectional area of the weld on the card with other pertinent data, such as the sound path and location of the weld defect.

4-95. The location and reflection pattern of a weld defect indicates its nature in many cases. For example, the logical conclusion of the weld defects described in figure 4-63, Example A is lack of fusion; figure 4-63, Example B, lack of penetration, and in figure 4-63, Example C, lack of penetration, and in figure 4-63, Example D, lack of fusion. Reflection patterns for gas, slag inclusions, and seams are illustrated in figure 4-60. A gas inclusion will give a relatively small reflection from all directions because it has a spherical shape. A slag inclusion has an irregular shape and its reflections will vary from all directions (see figure 4-60). Defects such as cracks, or seams lacks of penetration, and lack of fusion are direction sensitive and will only give a maximum reflection when the sound beam is perpendicular to their general direction. Any change will decrease the amplitude of the reflection abruptly, as illustrated in figure 4-60. Reflection patterns are graphically presented in figure 4-61. The following are procedures for scanning weldments to locate defects.

a. Place the angle transducer on the material at a distance of  $P/2$  from the center of the weld.

b. Determine this distance with the aids described in paragraphs 4-90 through 4-95. In this manner a reflection will be obtained from the root of the weld (V-weld). For "X" welds the distance should be chosen so that  $P/2$  reflects from the far side (or far top) of the lower weld bead as shown in figure 4-62.

c. Move the angle transducer systematically back and forward while scanning parallel to the weld. Follow the pattern shown in figure 4-63.

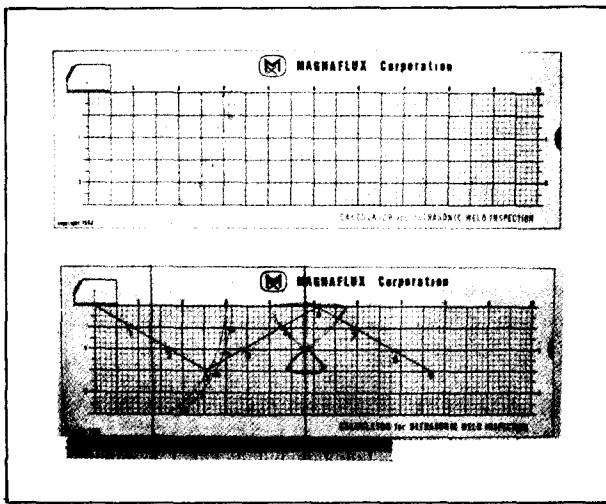


Figure 4-58. Calculator Card with Ruler and Slide

d. The length of the back and forward movement depends on the thickness of the plate and should be such that the complete weld is covered. Determine this with the visual aids described in paragraphs 4-90 through 4-95.

4-96. Use the following angles with thickness of materials as indicated:

MATERIAL THICKNESS	ANGLE IN DEGREES
0.25 in.	80
0.375 in.	75
0.500 in.	70
1.000 in.	60 - 70
1.500 in.	60
2.000 in.	45 - 60
2.500 in.	45
more than 2.500 in.	45 and 35

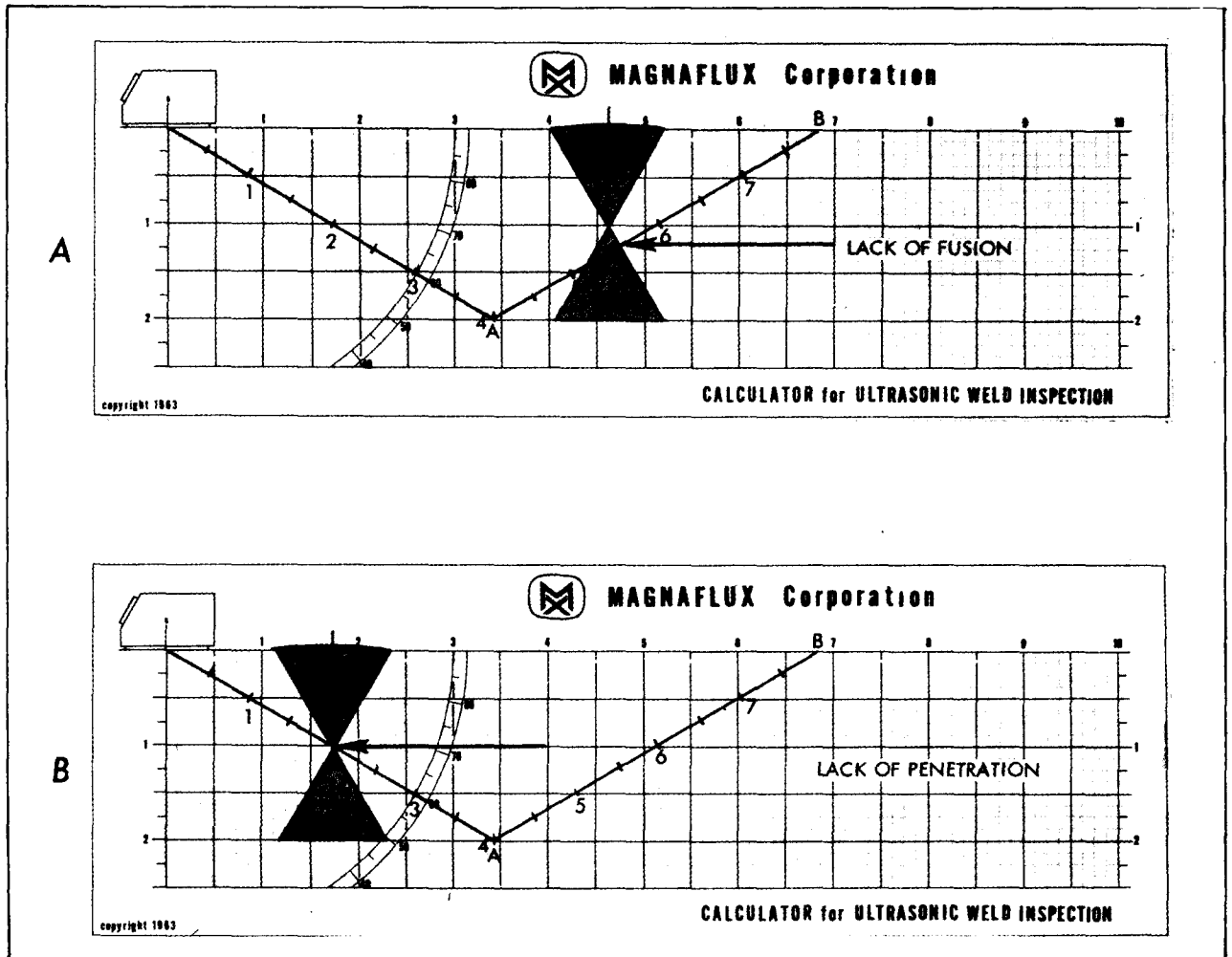


Figure 4-59. Examples for Use of Weld Calculator  
(Sheet 1 of 2)

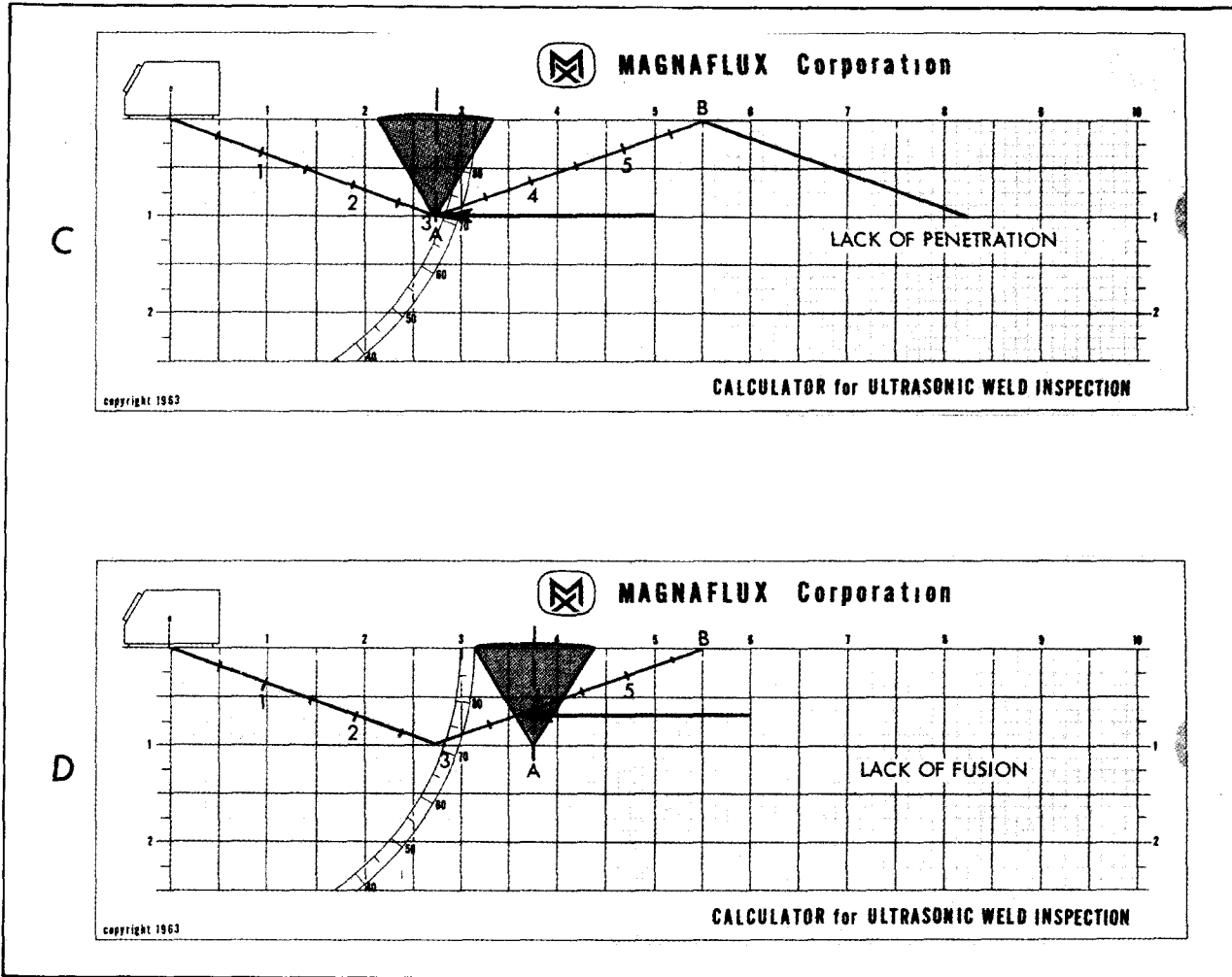


Figure 4-59. Examples for Use of Weld Calculator  
(Sheet 2 of 2)

4-97. If the wall thickness of the material under inspection is not known or lacks accuracy the following measurements are mandatory.

a. Use 5mc or 2.25 mc transducer (longitudinal) depending on the material. The highest frequency has preference because of better resolution.

b. Place the transducer on the reference block as described in paragraph 4-54. If 0.5 inch thickness reference block is used, the transducer should be placed as illustrated in figure 4-63 at a 0.5-inch range setting.

c. Adjust pattern with FINE RANGE control so that 10 reflections occur equally spaced across the cathode-ray tube display at every one-half inch mark.

d. Place the transducer on the material under inspection and obtain multiple back reflections. The

position of these back reflections is an indication for the thickness of the material. If, for example, the first reflection occurs exactly between the 0.5 inch and 1.0 inch mark the wall thickness is 0.75 inch. Increase accuracy by using more than one back reflection in the calculations. An example is illustrated in figure 4-65 where an unknown thickness is compared to the known thickness.

4-98. Accessories to facilitate the determination of wall thickness are available for several types of ultrasonic instruments; three methods are used.

a. Mechanical. An attachment is placed in front of the cathode-ray tube display. Two moveable pointers with micrometer adjustment are placed on the reflections and the thickness read directly. The difficulty is the parallax and increasing inaccuracy at smaller thicknesses.



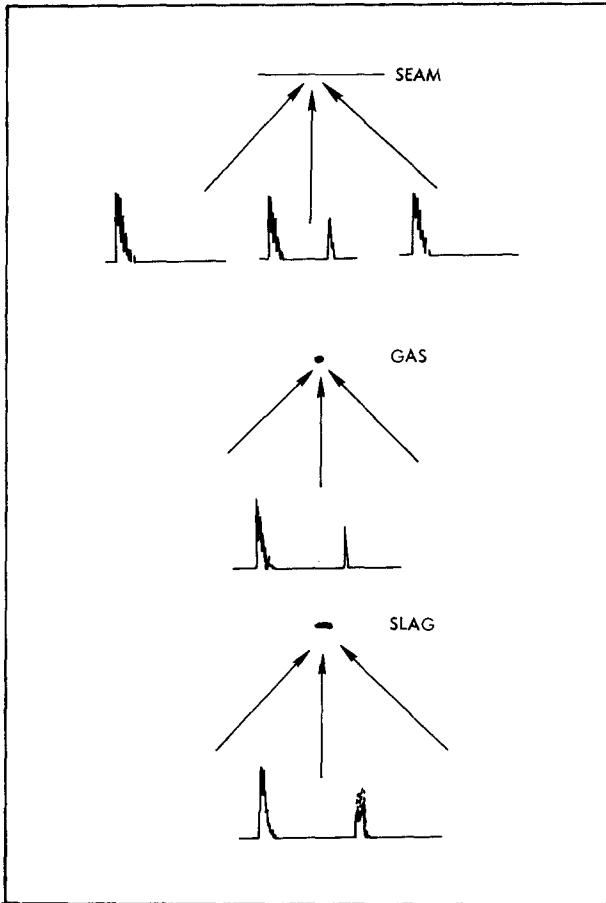


Figure 4-60. Reflection Patterns for Basic Type Defects

b. **Comparator.** Two transducers are used. One transducer is placed on the material under inspection. The other transducer is constructed in the attachment. The latter is placed in a column of liquid in which a reflector is placed. The distance between the reflector and the transducer can be varied. When the first transducer is placed on the material under inspection, the reflection from the attachment is lined up with the reflections from the material by adjusting the reflector. The reflector is mechanically connected to a direct reading scale. The drawback is that lining up of the reflections becomes difficult at smaller thicknesses (see figure 4-66).

c. **Electronic.** When the transducer is placed on the material a number of back reflections will occur in a definite time. This actually constitutes a frequency which depends on the thickness of the material. A second variable oscillator is placed in the attachment. When this oscillator is operating at the same frequency as that generated by the number of back reflections, a maximum amplitude will occur which is visible on the cathode-ray tube display. A direct reading scale on the variable oscillator is calibrated in wall thickness. The patterns obtained with this system are shown in figure 4-67. The drawback is that at least several multiple back reflections should occur or otherwise the measurement becomes impossible.

4-99. Thickness devices are usually calibrated for steel. Recalibration is necessary for other materials. The use of a factor is often more convenient. The factor is determined as follows:

$$\frac{C \text{ material X}}{C \text{ Fe.}} = \frac{X \text{ thickness}}{\text{Fe thickness}}$$

Example:

Material under inspection	Aluminum, Sound velocity	6300 m/sec
Reference block steel	Sound velocity	5900 m/sec
Measured wall thickness in steel		1.00 in.

Calculations:  $6300 = \frac{X}{1 \text{ in}} \times 5900$ ;  $X = 1.07 \text{ in.}$

4-100. Water alone is used as a couplant for the ultrasonic inspection of any materials that will be in direct or indirect contact with oxidizing liquids or gases.

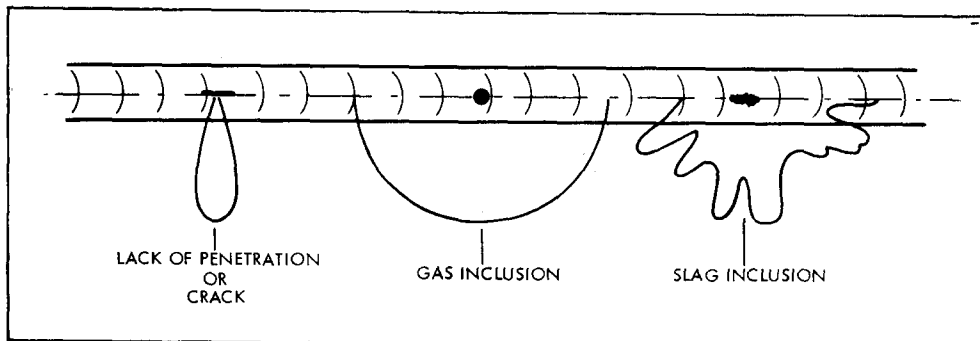


Figure 4-61. Graphic of Reflection Patterns

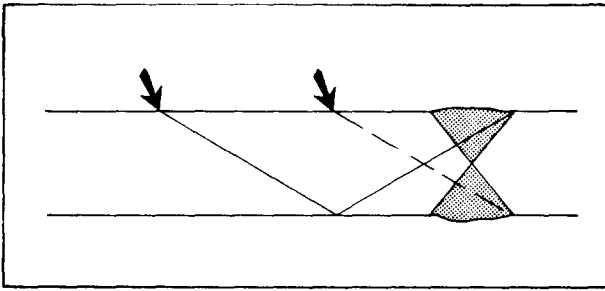


Figure 4-62. Reflection from Weld Bead

4-101. The classification of a weld will depend on the following:

- a. Number of defects.
- b. Nature of defects.
- c. Area of defects.

Classifications a and b will, in many cases, be the criterion for acceptance or rejection. The length of the defect can be determined in the manner as illustrated in figure 4-68. For defects where the diameter approaches the length, a direct comparison should be made with the classification charts or radiographs. Should a back reflection be obtainable, a comparison of the defect reflection can be made with the back reflection as illustrated in figure 4-69. The transducer is first placed on a sound part of the material and an attenuation curve traced. Secondly,

the maximum amplitude and location of the defect reflection is determined. If the defect is as large or larger than the transmitting crystal, a reflection equivalent to the back reflection is received at that point. This is the theoretical back reflection which can be determined from the attenuation graph. Thus the approximate area of the defect is  $\frac{F \cdot T}{\bar{B}}$  (T equals

the transmitting area of the transducer.) As the defect seldom has as smooth a reflecting surface as the back reflecting surface, inaccuracy is inherent to these measurements. An advantage over the use of artificial defects of known dimensions is the fact that the same material with the same acoustical properties is used, while interference is kept to a minimum or constant.

4-102. Based on the number, type and size of defects the weld may be classified according to the suggested procedure in paragraph 4-104. In some cases the use of a dual transducer system for the inspection of welds may be necessary. In figure 4-70 this system is schematically presented.

4-103. Figure E-5 lists the A.S.A. pipe schedules. Figure E-6 lists steel tubing specifications with relevant ultrasonic data.

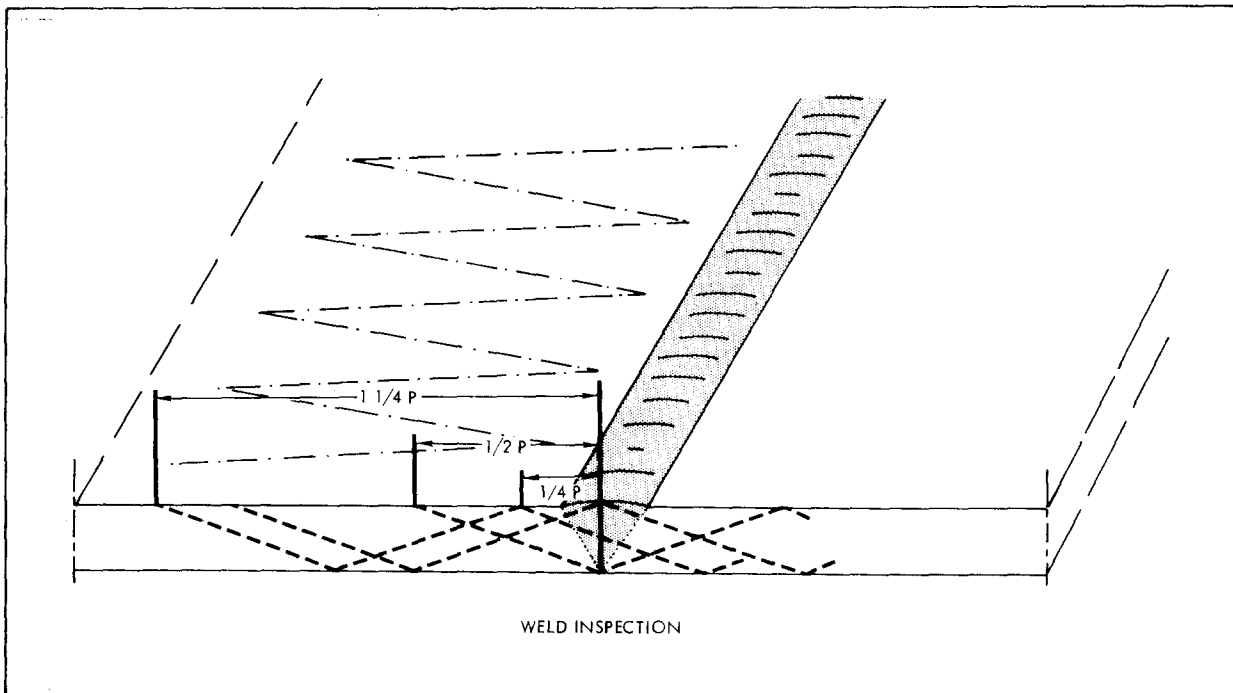


Figure 4-63. Scanning Pattern for Ultrasonic Weld Inspection

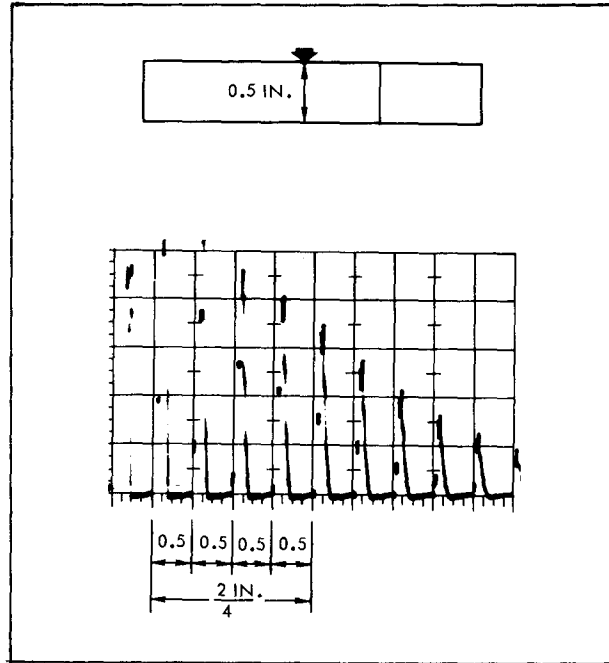


Figure 4-64. Adjustment for Thickness Measurement

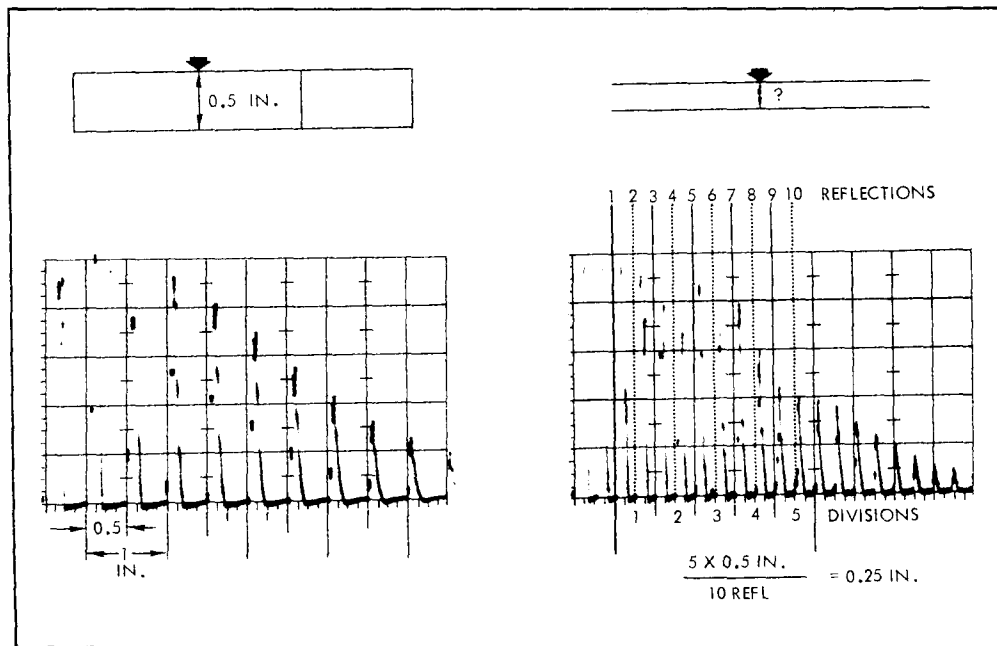


Figure 4-65. Comparison of Thicknesses with Multiple Back Reflections

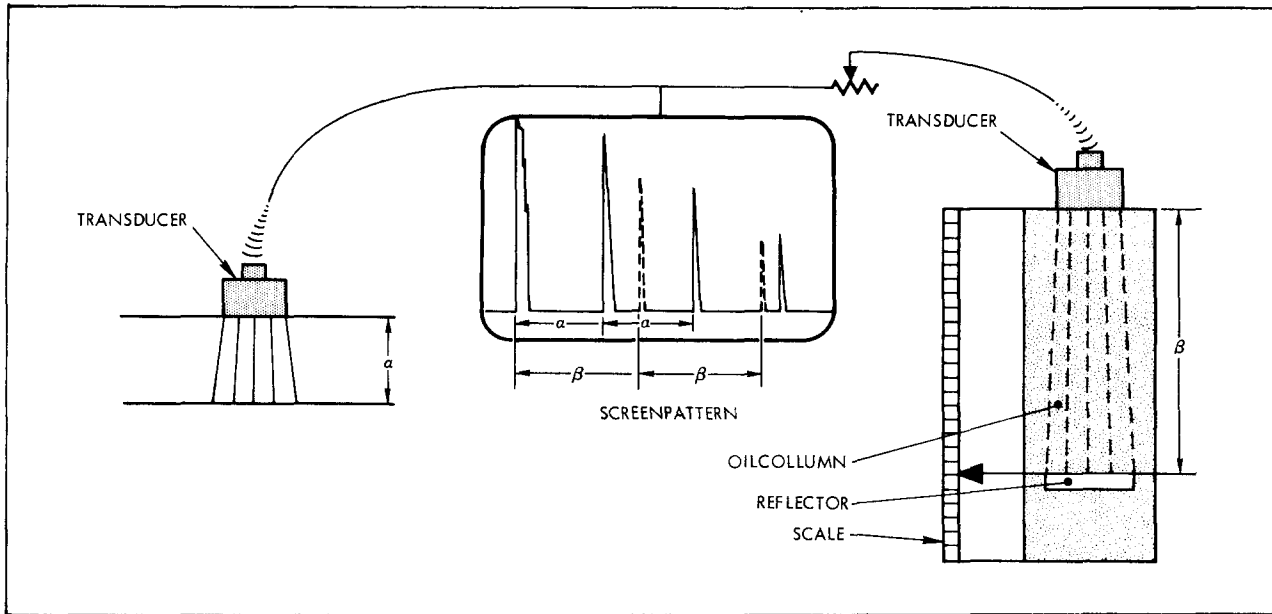


Figure 4-66. Comparator Method of Inspection

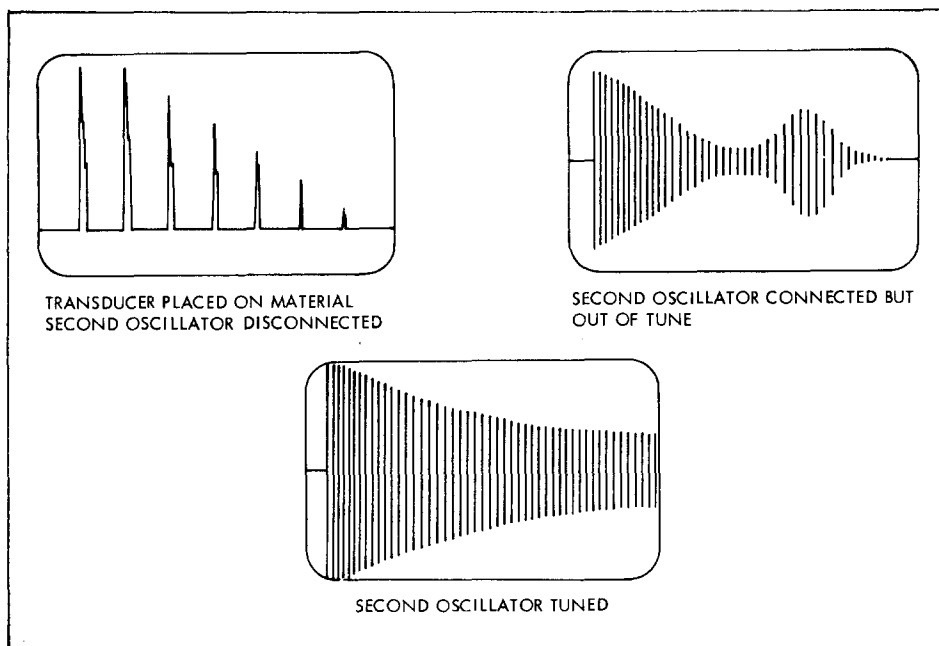


Figure 4-67. Electronic Comparator Method of Inspection

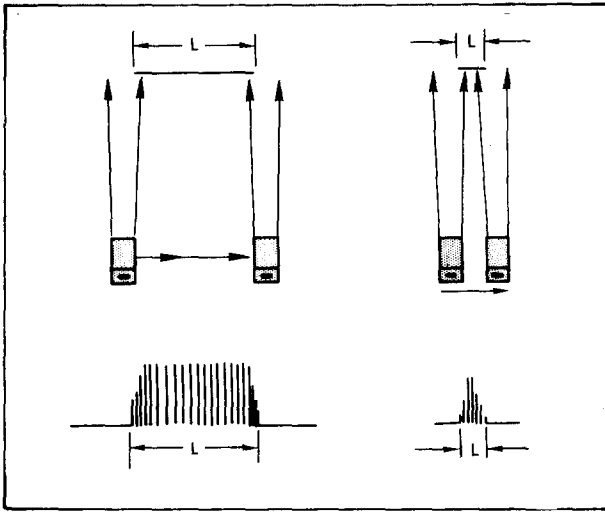


Figure 4-68. Determining Length of Defect

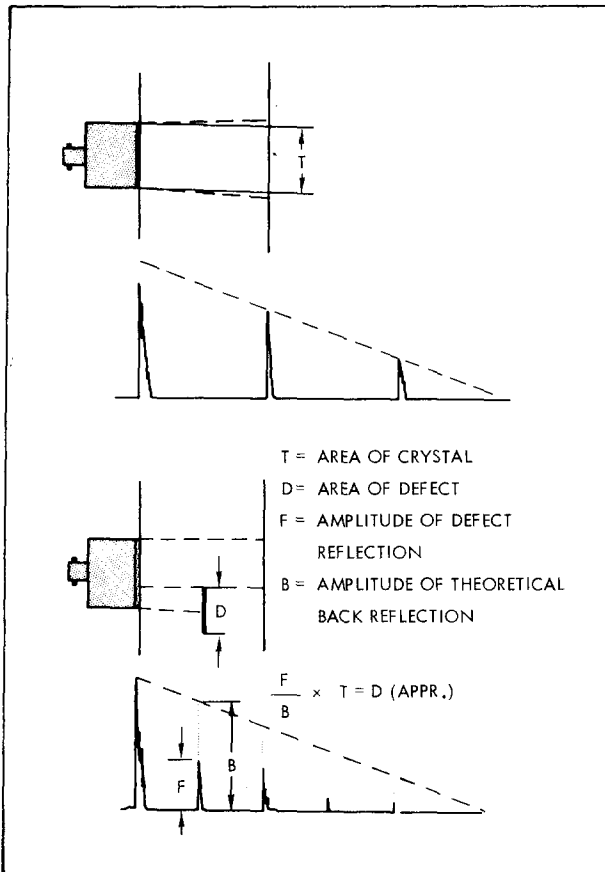


Figure 4-69. Approximate Defect Size Determination

**4-104. SUGGESTED PROCEDURES FOR CLASSIFICATIONS OF WELDS.**

4-105. Figures 4-71, 4-72, 4-73, 4-74 and 4-75 list five classes of weld quality complete with the radiographs, ultrasonic oscilloscope patterns and sensitivity levels. Cross sections of the welds are also shown. Figure 4-76 shows the degree of acceptability based on non-destructive tests, divided into five classes. Figure 4-77 lists type designation, type of weld defect and defect symbols used in ultrasonic weld inspection. Defect type designations divide weld defects into seven main categories.

**NOTE**

The design engineer will indicate the minimum classification of acceptability for all welds. The classification shall appear in the engineering data for the respective weld(s). Assistance in establishing acceptance and rejection standards by the design engineer can be obtained from the "Tentative Reference Radiographs for Steel Welds, ASTM designation E99-55T or the Reference Radiographs of the International Institute of Welding."

4-106. DESCRIPTION OF WELD DEFECTS. Refer to figure 4-78 for description of weld defects with regard to cause, nature, and characteristic pattern on radiograph.

4-107. DESIGN AND MANUFACTURE OF WELD INSPECTION STANDARDS.

4-108. It is impossible to have available inspection standards which cover every possibility. Whenever warranted a standard can be originated utilizing non-destructive testing methods other than ultrasonics. A sample must be welded whereby the same material, shape, and dimensions are used as far as possible. The sample is radiographically inspected using optimum techniques, that is; fine grain film and exposures from three directions as shown in the classification charts figures 4-71 through 4-75. The weld is also subjected to magnetic particle inspection if the material is ferro-magnetic or fluorescent penetrant inspection for non-magnetic materials. A thorough visual inspection of the weld is essential. Defects found in the weld are clearly marked and identified. Should the weld be perfect, another sample must be made by a less experienced welder. When the level of acceptability for the sample weld has been established, an ultrasonic inspection is performed under supervision. The sensitivity adjustment levels are established according to paragraph 4-65. Photographs of the screen patterns characteristic for certain defects should be made. With this information a similar classification chart can be drawn up as

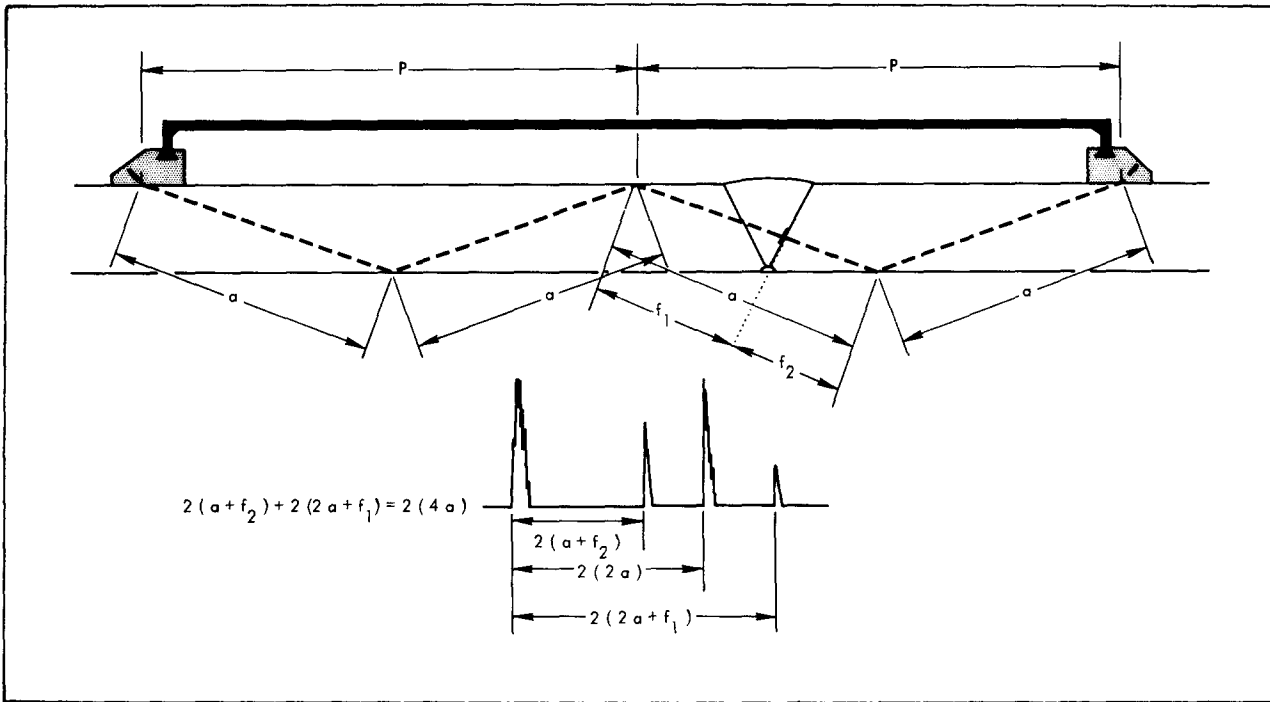


Figure 4-70. Dual Transducer System for Inspecting Welds

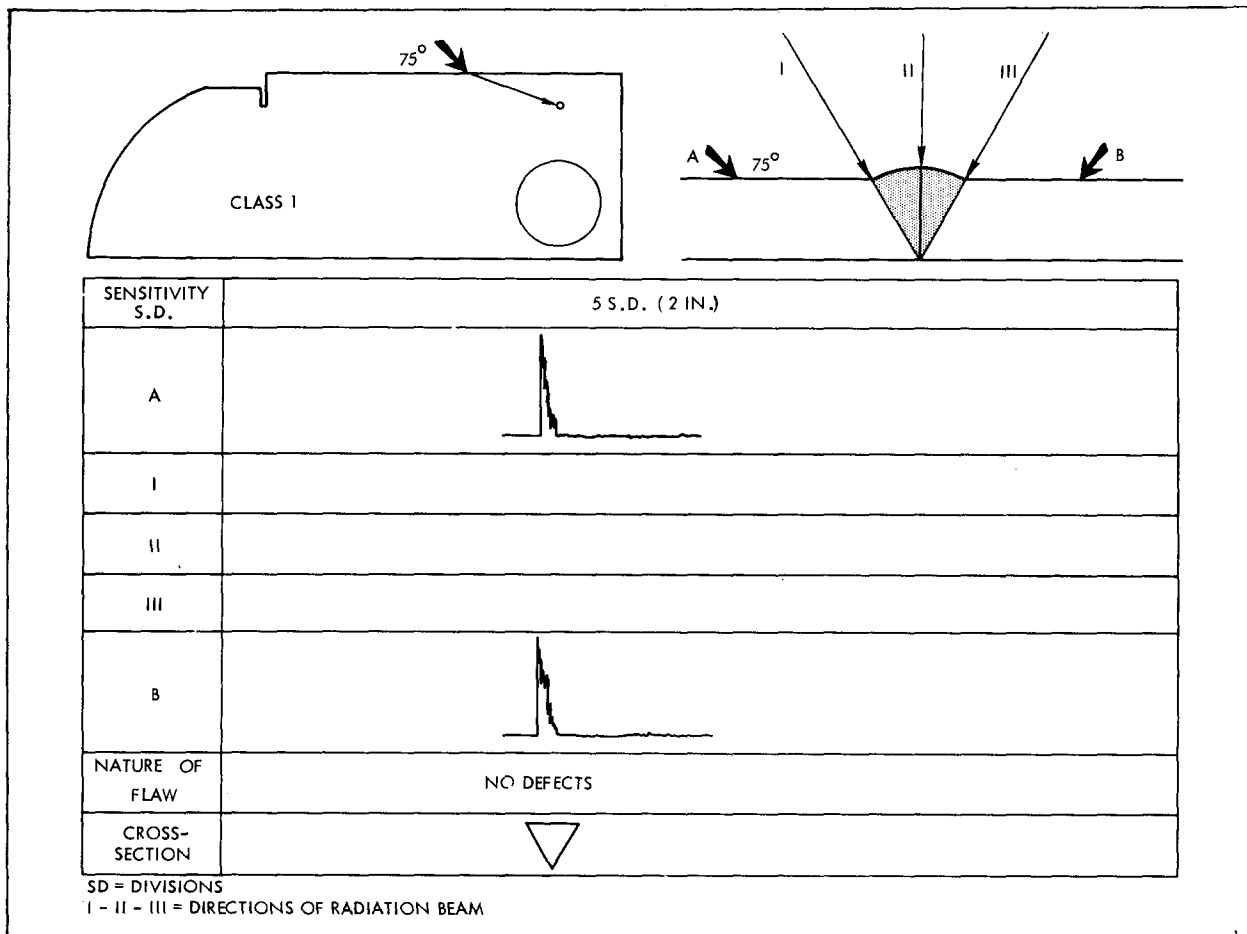


Figure 4-71. Class I Classification of Welds

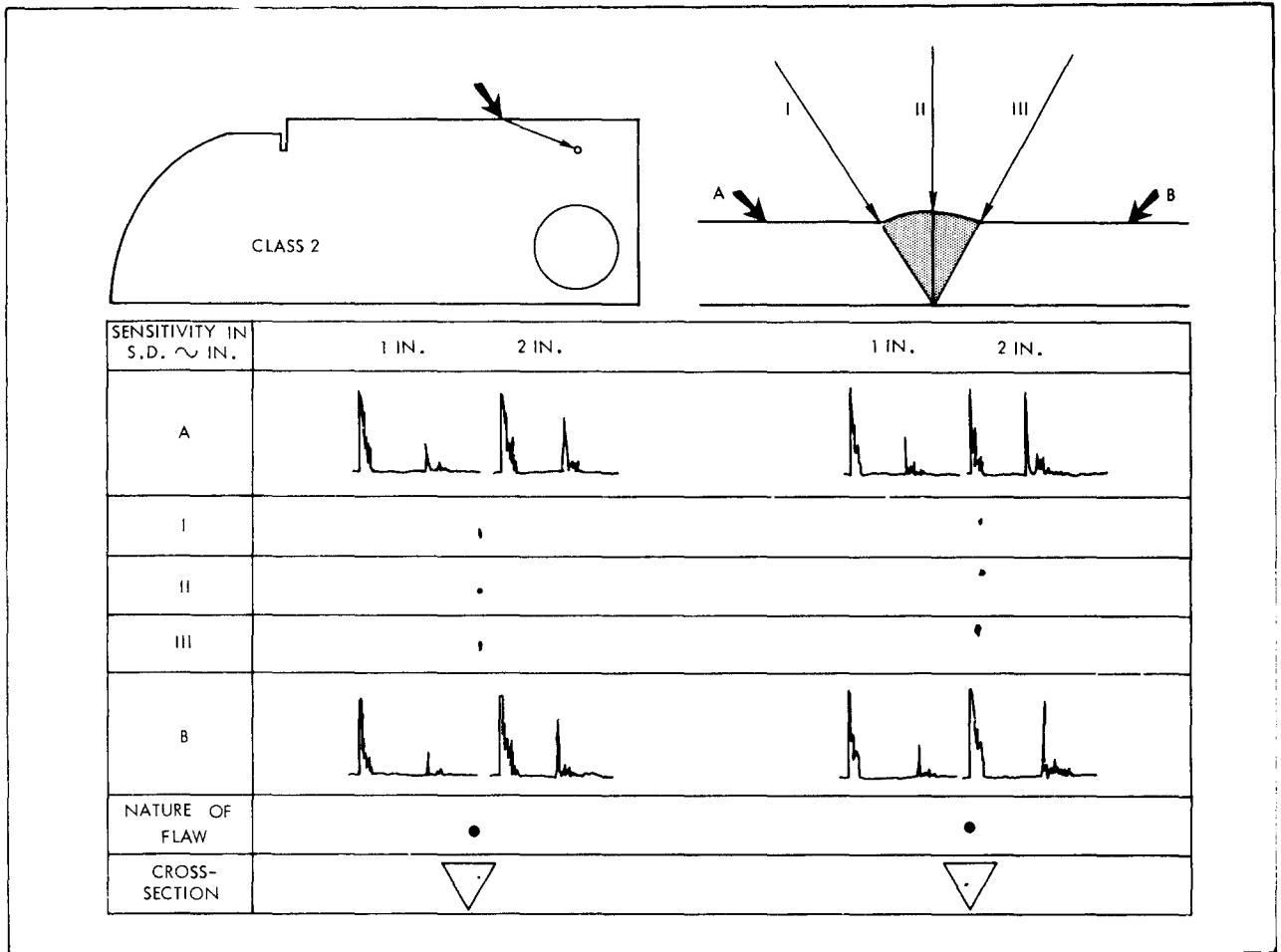


Figure 4-72. Class II Classification of Welds

shown in figures 4-71 through 4-75. Also, the necessary information regarding frequency, type of transducer and, couplant must be given. If sufficient samples are available, a metallurgical test of the defective weld areas will give valuable additional information which represents a macro-examination and a corresponding ultrasonic cathode-ray tube display (see figure 4-79). Where mechanical properties are to be correlated with the cathode-ray tube display, a specimen may be taken from the questionable weld area for tensile or bond test. An example is illustrated in figure 4-80. This information can be used in preparation of acceptance and rejection standards for weld inspection.

4-109. EDDY CURRENT METHODS OF INSPECTION.

4-110. BASIC EDDY CURRENT THEORY. The eddy current system of non-destructive testing and inspection of parts is based on three principles.

a. A primary magnetic field is established by introducing an alternating current through a coil. The primary magnetic field has an overall field strength designated as  $H_p$  (See figure 4-81).

b. When the coil is placed in the vicinity of a material such as aluminum or copper, the rapidly alternating magnetic field  $H_p$  induces eddy currents which flow in a circular direction in the test part.

c. The eddy currents cause a secondary magnetic field, which is less than and opposed to, the primary magnetic field  $H_p$ . The secondary magnetic field is designated  $H_s$ .

4-111. The field intensity of the coil is first measured without reference to its proximity to a test part. The coil is then placed against the test part and the intensity of the coil is measured in that position. It is observed that the intensity of the coil is now

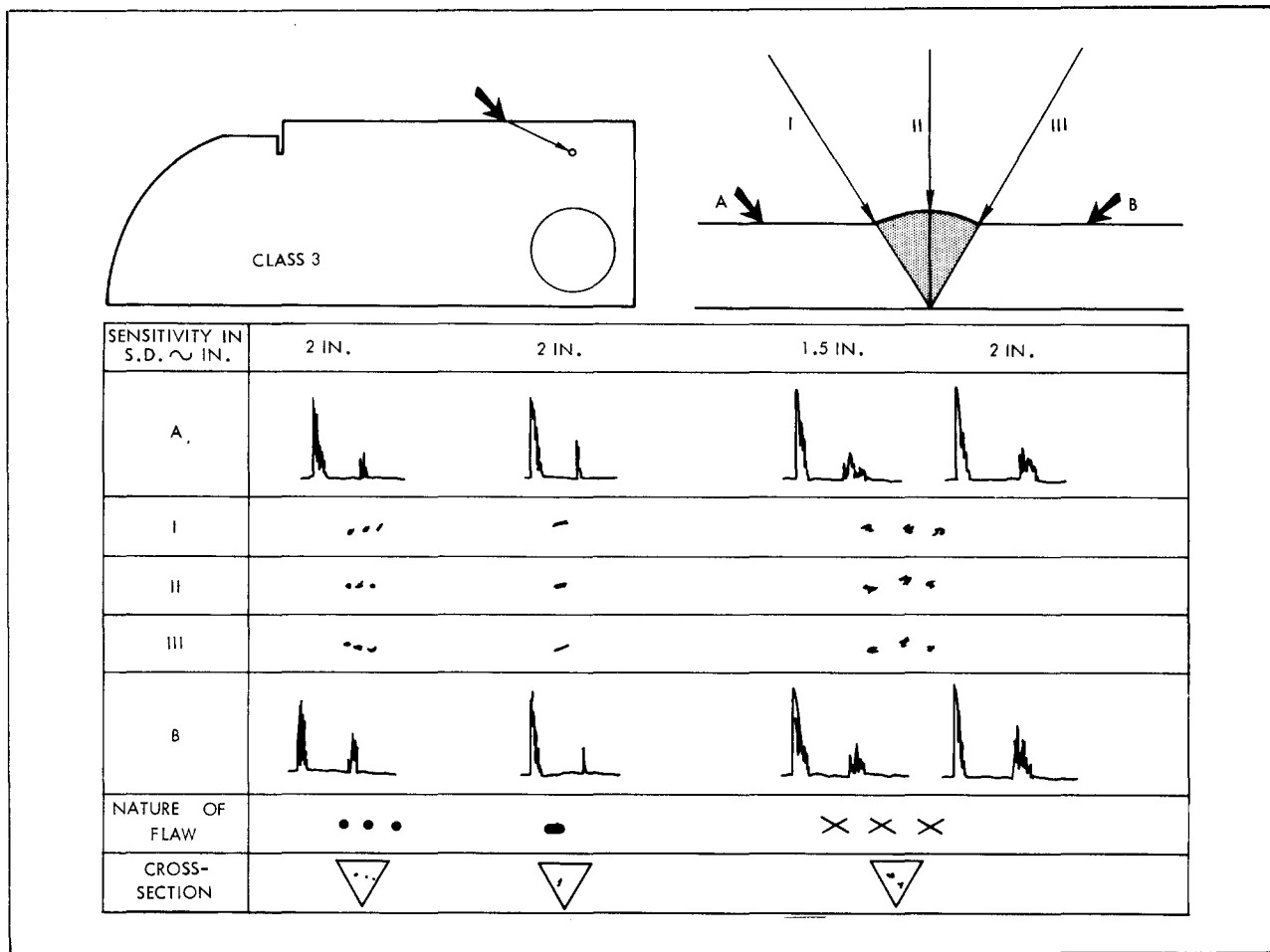


Figure 4-73. Class III Classification of Welds

less than the original measurement and is equal to  $H_p$  minus  $H_s$ . Thus two magnetic fields exist which are imposed upon each other, indicating that a different magnetic field exists when the test coil is not adjacent to the test part and when the test coil is adjacent to a test part.

**NOTE**

The change in the field intensity of the coil where the coil is less than the original measurement is equal to  $H_p$  minus  $H_s$ , is only true where non-magnetic test parts are used.

4-112. Figure 4-82 illustrates a test coil with the primary magnetic field designated as  $H_p$  and the test part inserted in the coil, having induced eddy currents designated as  $H_s$  which is the second magnetic

field. The same effect of inducing a second magnetic field can be had by inserting the test part within the coil instead of placing the test part adjacent to the test coil as illustrated in figure 4-81.

4-113. TEST COILS. Test coils are characterized electrically as having two values:

- a. Inductive reactance  $\omega L$ .
- b. Ohmic resistance  $R$ .

4-114. Figure 4-83 illustrates the inductive reactance  $\omega L$  plotted on the y axis and the ohmic resistance  $R$  plotted on the x axis. When both the reactance and ohmic resistance of the test coil is measured without reference to a test part, the impedance of the test coil is determined by finding the vectorial sum of the two values. As soon as the test part is placed against the test coil, the original magnetic field of the test coil changes as a result of the superimposed eddy current field induced in the test part. The varia-



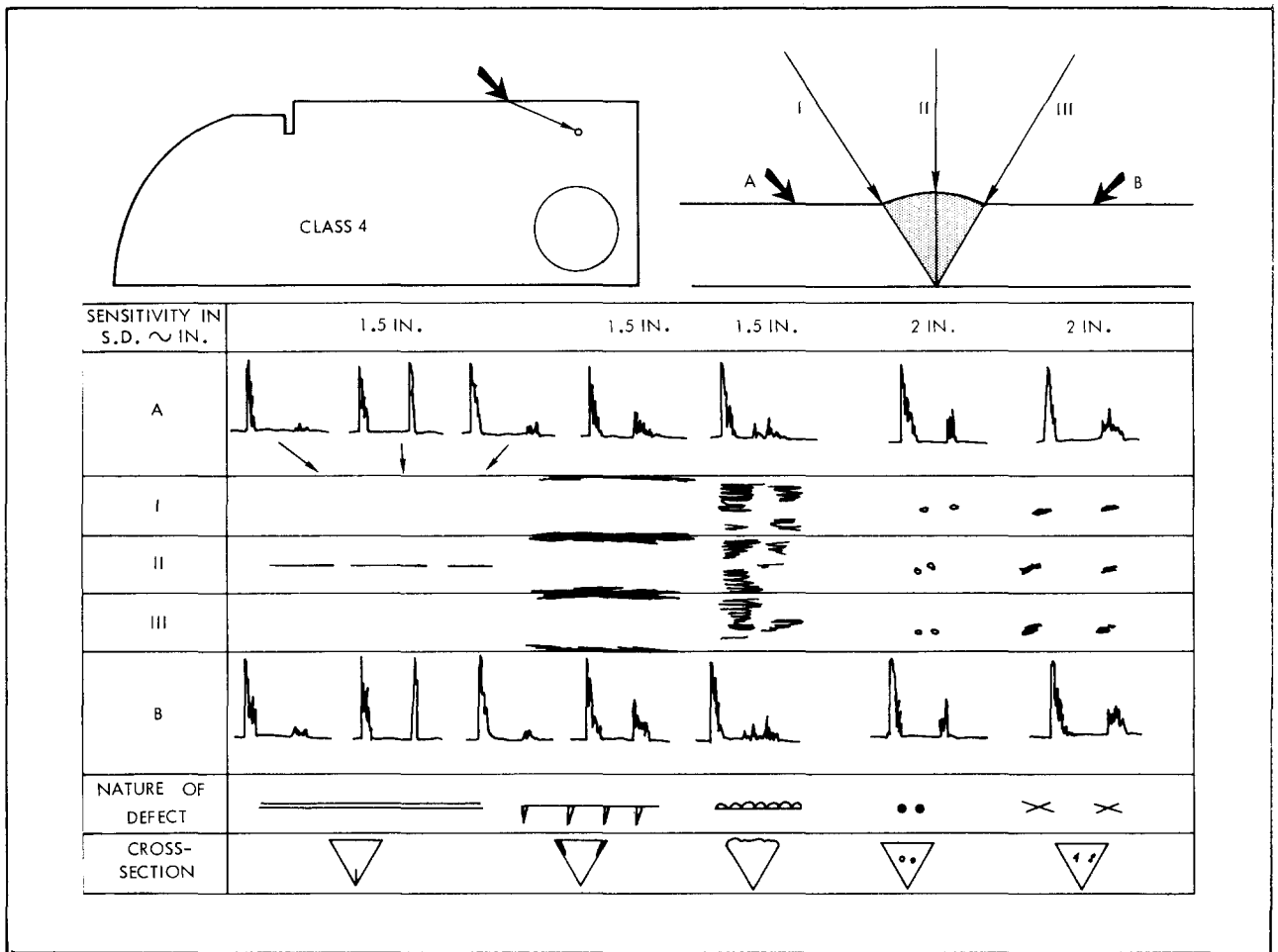


Figure 4-74. Class IV Classification of Welds

tion of the test coil field has the same effect as the characteristics of the test coil itself would have changed, so that the effect of the test part on the test coil is described as a variation of the test coil characteristics as a result of the change of impedance. Figure 4-83 illustrates this variation where  $P_0$  ( $\omega L_0$  and  $R_0$ ) represent the impedance of the test coil, without reference to a test part, and which variation is displaced by the change in impedance to  $P_1$  ( $\omega L_1$  and  $R_1$ ), when the test coil is placed against the test part. Three values can be measured and are an indication of the change in impedance which has taken place. These values are:

- a. The distance from the points  $P_0$  to  $P_1$  -  
..... Magnitude
- b. The angle  $oc$ , direction of the change -  
..... Direction
- c. The rate of change in moving along the distance  $P_0$  to  $P_1$   
..... Rate

4-115. PROPERTIES OF TEST PARTS AND EQUIPMENT CHARACTERISTICS.

The variation of impedance in the test coil is affected by properties of the test part such as electrical conductivity, dimensions, magnetic permeability, and presence of heterogeneities. The impedance change in the test coil is also affected by variables in the test part such as alloy, hardness, heat-treat condition, structure, impurities, stresses, diameter change, thickness change, density change, surface condition, temperature, defects, etc.

4-116. Impedance of the test coil is also affected by the following characteristics of the test instrument:

- a. Frequency of the alternating-current field of the test coil.
- b. Size and shape of the test coil.
- c. Distance of the test coil from the test part.

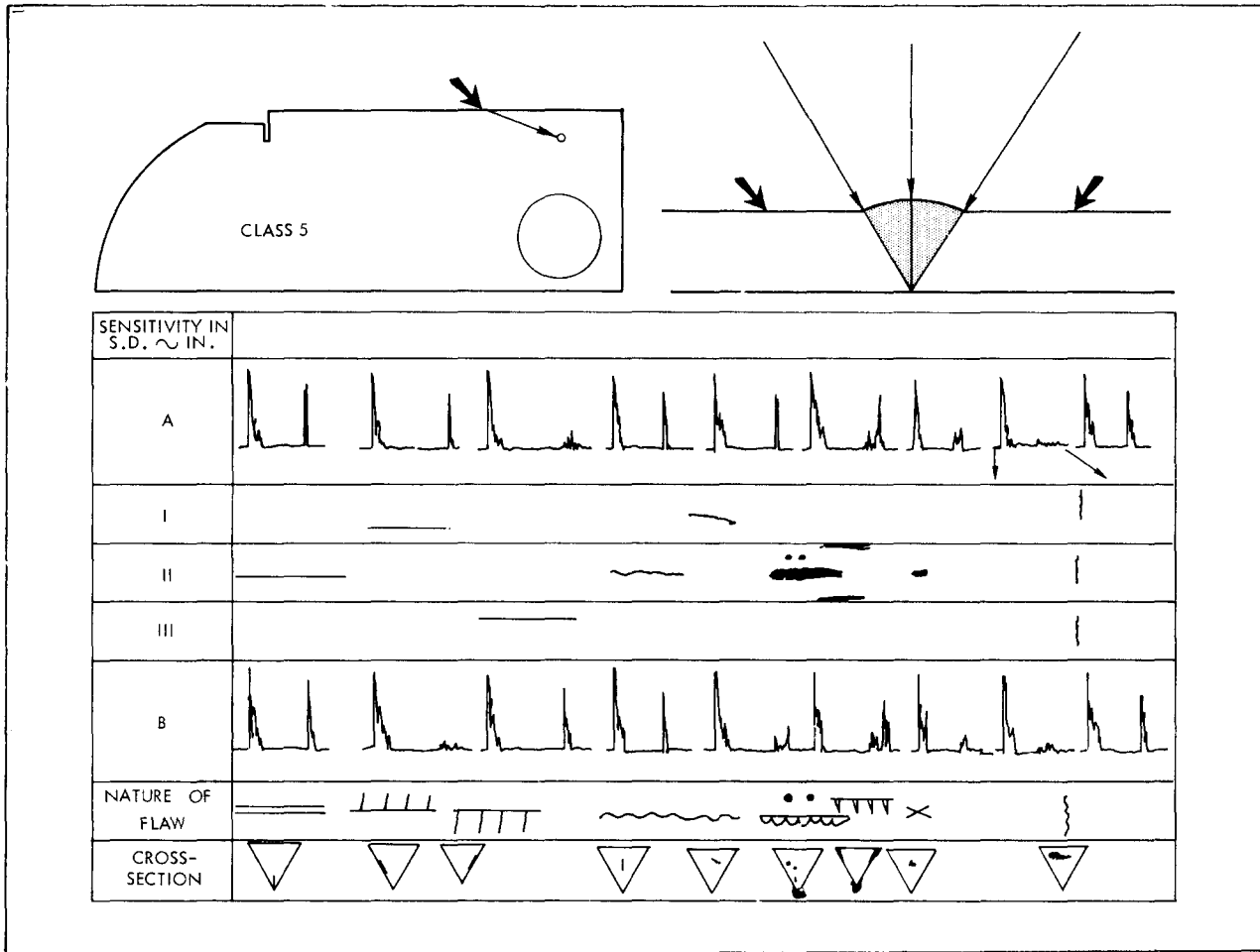


Figure 4-75. Class V Classification of Welds

4-117. **MEASURING IMPEDANCE.** When the same coil is placed in the same way in a test part and the impedance of the coil is measured as to magnitude, direction, and rate, and relate one or more of these changes to a change in material properties in the test part, the performance is that of non-destructive testing of test parts with the use of eddy currents. The change in coil impedance can be measured by placing a secondary, or pickup coil, inside the primary coil in such a way that when the test part is placed in the test coil, it is within both the primary and the pickup coil. By connecting a sensitive meter across the leads of the pickup coil, the change in impedance of the primary coil varies the current flowing through the pickup coil and thus the voltage across the coil. This arrangement detects changes in magnitude of the coil impedance only. Phase-sensitive circuitry is necessary to detect variations in the direction of the impedance change. Were a test part to consist of a rod which completely fills the test coil, the coil impedance will vary as indicated in figure 4-84. The x values are given in terms of ohmic resistance R and the y values in terms of inductive reactance  $\omega L$ .

4-118. All test parts have a characteristic frequency designated as  $f_g$  which is calculated by the formula:

$$f_g = \frac{5060P}{\mu \cdot d^2}$$

Where:  $1/p$  = Conductivity per ohm per square millimeter

$\mu$  = Permeability

$d$  = Diameter of the rod

The characteristic frequency of the test part  $f_g$  (see figure 4-84), bears an important relationship to the operating frequency  $f$  of the test coil. Assuming that the resistance of the test coil is negligible, without reference to a test part, the impedance of the test coil is indicated at the upper end of the curve. By calculating the characteristic frequency  $f_g$ , then the ratio  $f/f_g$  equals 1.0. The coil impedance with the test rod inserted in the test coil is then represented by the point marked 1.0 on the curve.

4-119. Were the test rod to be replaced by another rod which is identical in every respect to the first rod (a rod which completely fills the test coil) except that conductivity  $1/p$  is four times greater, the coil impedance will change. The characteristic frequency  $f_g$  will decrease as conductivity increases.

The decrease in characteristic frequency will increase the ratio  $f/f_g$  and this ratio increases with increasing conductivity. The impedance of the test coil, when using the second test rod, will increase and is represented by the point 4.0 on the curve (See figure 4-84). The rod completely fills the test coil. The points along the curve are marked at various values of the ratio of the operating frequency to the characteristic frequency of the test part  $f/f_g$ , as the conductivity of the test rod is increased and all other values, including the operating frequency  $f$ , are held constant. The change in coil impedance will change the magnitude and the phase of the voltage across the coil. It is essential that either the change in magnitude and the phase of the voltage, or both, can be detected. Assume that a series of rods be used with this test coil, which are identical in every respect, except that the diameter varies. The ratio of the cross-sectional area of the test part to the cross-sectional area of the test coil, is termed the fill factor and designated as  $n$ . (See figure 4-85). The illustration

shows test coil impedance curves for various values of the fill factor  $n$ . The curve indicated by  $n = 1.0$  is the same curve illustrated in figure 4-84, where the rod completely filled the test coil. The curve  $n = 0.75$  indicates changes in coil impedance caused by rods filling only 75 percent of the test coil and differing only in conductivity. The curve  $n = 0.050$  indicates rods filling only 50 percent of the test coil. Broken lines shown in figure 4-85 represent changes in coil impedance when the conductivity of the test rods is constant and only the diameter varies. The change in coil impedance caused by a change in diameter differs in phase from the change in impedance caused by a change in conductivity.

4-120. Although phase-sensitive circuits can distinguish between changes in diameter and changes in conductivity, differentiation in changes is much easier in the higher  $f/f_g$  ranges where the angle between the curves is much greater than the angle between curves in the low  $f/f_g$  ranges when the curves are practically parallel. The operating frequency should be increased to result in an  $f/f_g$  ratio greater than four, for this differentiation. The use of a phase-sensitive circuit is further advisable as indicating that a crack in the test part will change the impedance in still another phase than either fill factor or conductivity.

CLASS	DESCRIPTION	DEGREE OF ACCEPTABILITY	FIGURE
1	Homogeneous weld without flaws.	Acceptable for all critical structures and environmental conditions.	4-71
2	Weld with minor flaw such as an isolated gas inclusion. (Refer to Figure 4-78. Type Designation A1)	Acceptable for all critical structures.	4-72
3	Weld with several small flaws such as gas or slag inclusions. (Refer to Figure 4-78 Type Designation A or B)	Acceptable in critical construction as restricted by design engineer.	4-73
4	Weld with flaws such as gas and slag inclusions, undercut, lack of penetration and excessive weld bead.	Acceptable only for non-critical structures.	4-74
5	Weld with flaws such as gas and slag inclusions, undercut, lack of penetration, lack of fusion, and excessive weld bead, cracks.	Not acceptable under any circumstances.	4-75

Figure 4-76. Classification of Weld Defects and Degrees of Acceptability

TYPE DESIGNATION	TYPE OF WELD DEFECT	SYMBOL
A	GAS INCLUSIONS	• • • • •
A1	Porosity	
A2	Piping	— — —
B	SLAG INCLUSIONS	
B1	Any shape or direction	
B2	Slag lines	
B3	Weaving faults	× × × ×
B4	Bad chipping	
B5	Faults at electrode change	
B6	Faults at junction of seams	
C	LACK OF FUSION	/ / / /
D	INCOMPLETE PENETRATION	= =
E	CRACKS	
E1	Longitudinal cracks	~~~~~
E2	Transverse cracks	}
F	UNDERCUT	∨ ∨ ∨ ∨
G	EXCESSIVE WELD BEAD	
G1	Extremely rough weld surface	○○○○○○○○
G2	Excessive penetration (dinkelberries)	○○○○○○○○

Figure 4-77. Classification of Welds and Weld Symbols

TYPE DESIGNATION AND CLASSIFICATION	NATURE AND SHAPE OF WELD	RADIOGRAPHIC INSPECTION INDICATION
<b>GAS INCLUSIONS</b>		
A1 Porosity	Cavities filled with gas due to fast solidification of the melt.	Sharply defined dark shadows with rounded shapes.
A2 Piping	Elongated cavities filled with gas due to fast solidification of the melt.	Sharply defined dark shadows of rounded or elongated shape, depending upon the direction of the flaw.
<b>SLAG INCLUSIONS</b>		
B1 Any shape or direction.	Slag or other non-metallic substances trapped in the weld metal after solidification.	Dark shadows of irregular shape
B2 Slag lines.	Elongated cavities filled with slag or other non-metallic substances.	Dark, irregularly interrupted lines in a longitudinal direction.
B3 Weaving faults.	Slag inclusions due to faulty weaving motion during operation.	Dark shadows of irregular shape generally evenly spaced along the sides of the weld.
B4 Chipping faults	Slag inclusion caused by the wrong weld opening for a counter weld due to the use of chisels of the wrong shape.	Generally two parallel dark lines sharply defined on the side of the parent material, but irregularly shaped on the weld side.
B5 Electrode change faults	Shrink cavities caused in the melt during interruption in welding and immediately following solidification.	Dark shadows of irregular shape.
B6 Faults at seam junctions	Slag or other non-metallic substances trapped in the weld metal after solidification.	Dark shadows of irregular shape.
<b>LACK OF FUSION</b>		
C	A "two-dimensional" discontinuity due to a lack of fusion between the weld metal and the parent material.	Thin dark line sharply defined. Detection depends upon the direction of the axis of radiation with respect to the weld opening.

Figure 4-78. Description of Weld Defects  
(Sheet 1 of 2)

<u>TYPE DESIGNATION AND CLASSIFICATION</u>	<u>NATURE AND SHAPE OF WELD</u>	<u>RADIOGRAPHIC INSPECTION INDICATION</u>
LACK OF PENETRATION		
D	Lack of fusion in the root of the weld or an opening in the root of the weld not filled with weld material.	Continuous dark line with some interruption in center of weld.
CRACKS		
E1 Longitudinal, Transverse, heat affected zone cracks	Discontinuities caused by break in material.	Fine dark lines; irregular pattern.
UNDERCUT		
F	Opening along the side of the weld in the surface of the plate.	Dark line; sometimes wide and hazy, along the side or sides of the weld.
EXCESSIVE WELD BEAD		
G1	Extremely rough weld surface with sharp grooves and extreme variations in height.	Irregular dark and light spots, making an interpretation of the film difficult if not impossible.
G2	Excessive amount of weld metal on the underside of the weld in varying quantities.	More sharply defined dark and light spots in the center area of the weld, making interpretation of the film difficult if not impossible.

Figure 4-78. Description of Weld Defects  
(Sheet 2 of 2)

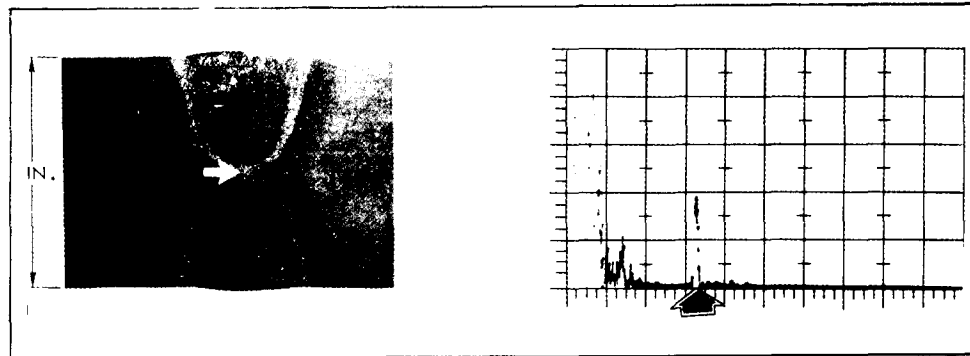


Figure 4-79. Lack of Penetration with Characteristic Cathode-Ray Tube Display

4-121. Figure 4-86 illustrates impedance changes caused by surface and sub-surface defects, conductivity, and fill factor. Assume that point A represents an impedance of a good test part. A decrease in diameter of the test part to one percent, brings the impedance to point B. An increase in diameter of the test part changes the impedance along the line of fill factor in either way. An increase of conductivity of five percent changes the impedance to point C along the line of conductivity. A surface crack of 20 percent of the wall thickness of the test part changes the impedance along the line of conductivity to point D. A 3.3 percent defect of the wall below the surface of the test part, and having a depth of 30% of the wall thickness will change the impedance along the line to point E. Cracks in the test part at other positions, with respect to the surface will change the impedance along any line between points D and E. Any point along the circle illustrated in figure 4-86, with point A representing the center of the circle and the impedance of a good test part, has the same magnitude of impedance change but a different phase. For example:

- One percent in diameter.
- Seven percent change in conductivity.
- Five percent depth of a surface crack.

This means that the use of phase sensitive equipment is necessary for many applications.

4-122. DEPTH OF PENETRATION. The effective depth of penetration of eddy currents is that depth where the magnitude of the eddy currents is decreased to one-third of the magnitude at the surface.

This depth of penetration depends on:

- Permeability.
- Conductivity.
- Frequency.

Depth of penetration is calculated as follows:

$$\frac{1}{\sqrt{\text{Permeability} \times \text{Conductivity} \times \text{Frequency}}} = \text{in.}$$

% I A C S                      Kc

For example:

$$\text{Brass-16 percent IACS} \quad \sqrt{\frac{1}{1 \times 16 \times 1}} \text{ in} = 0.25 \text{ in.}$$

Frequency-1 Kc

#### 4-123. INSTRUMENTATION.

4-124. The basic principle of operation for all eddy current equipment is illustrated in the block diagram figure 4-87. An alternating-current signal is generated by an oscillator. This signal is amplified and applied to a solenoid which is part of the measuring circuit. The impedance variations of the solenoid, due to the measuring conditions, are amplified and indicated on a display system, (oscilloscope, meter, tape recorder, etc.) The frequency of this signal, which is applied to the solenoid, can vary from 60 cycles up to 1 mc, though usually the following frequencies are standard.

60 cps, 360 cps, 1 kc, 5 kc, 10 kc, 15 kc, 25 kc,  
60 kc, 100 kc, 125 kc, 200 kc, 625 kc.

4-125. The use of a frequency depends on the application. In general it can be noted that the lower the electrical conductivity of the material the higher the frequency and the higher the electrical conductivity the lower the frequency must be. In figure E-7, a list of the electrical conductivities in percent of the International Annealed Copper Standard for a number of non-magnetic materials is given. For calculation into specific resistivity the following formula is used:

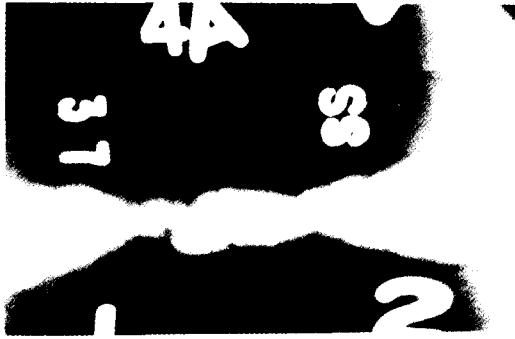
$$R_s = \frac{172.41}{\% \text{ IACS}} \text{ Microhm - cm. at } 20^\circ\text{C.}$$

or

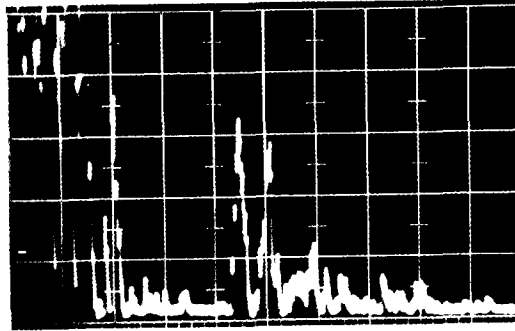
$$R_s = \frac{1037.1}{\% \text{ IACS}} \text{ ohm/circular mil-ft. at } 20^\circ\text{C.}$$

PIPE 4<sup>a</sup>  
section 1-2

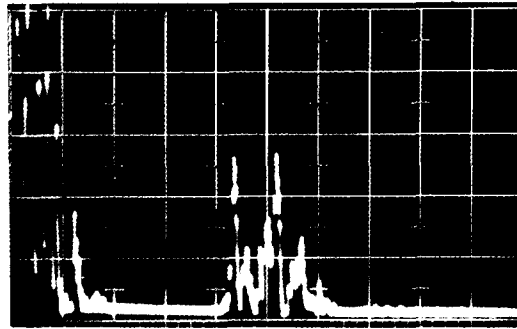
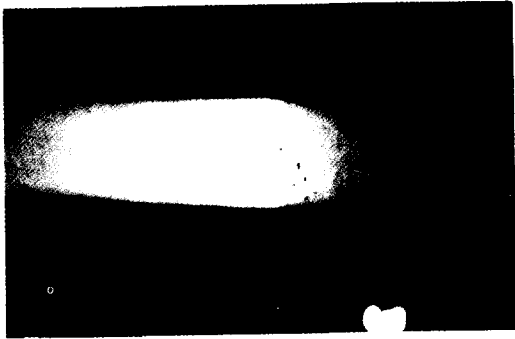
X RAY



ULTRASONIC



original condition



without weldbead

TENSILE TEST 25,200 LBS. ULT.

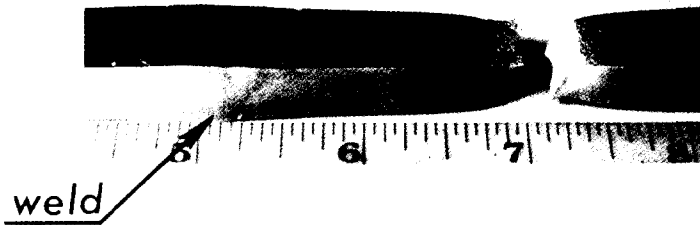


Figure 4-80. Ultrasonic Radiographic and Metallurgical Data of Weld Sample



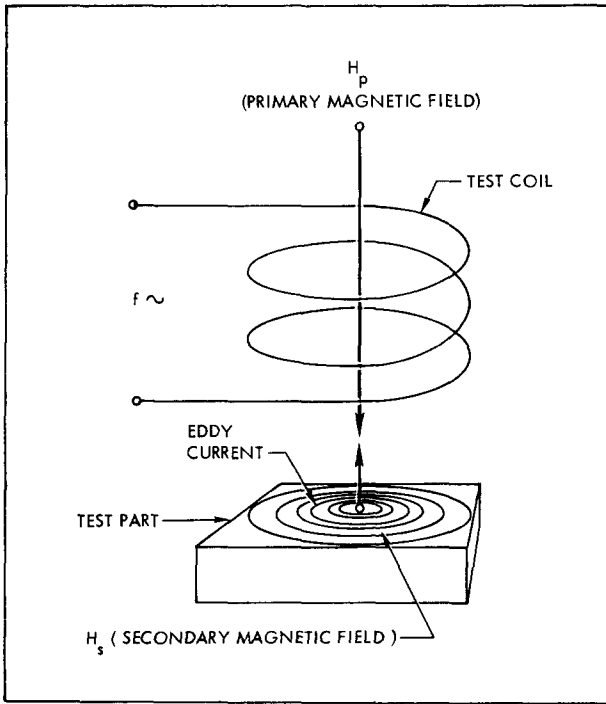


Figure 4-81. Test Coil Adjustment to Test Part Indicating Primary and Secondary Magnetic Fields

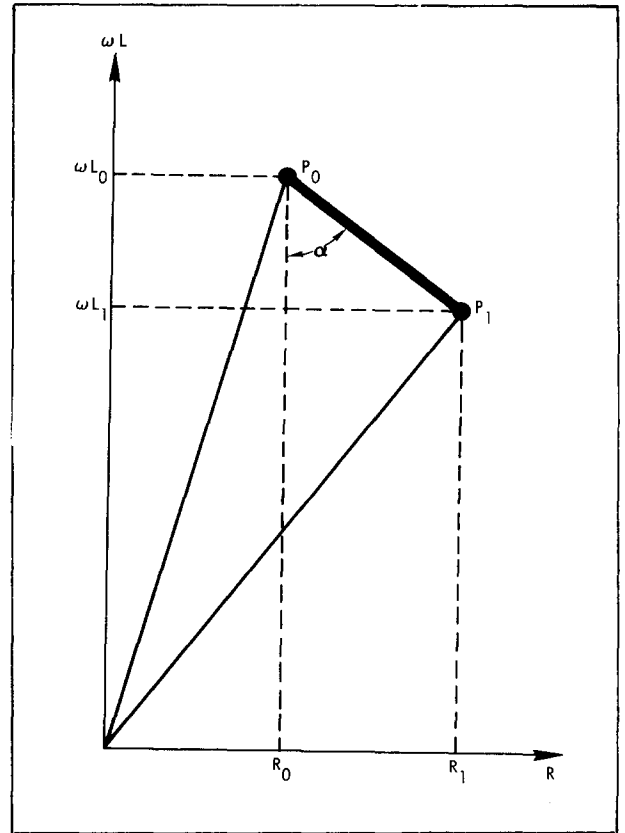


Figure 4-83. Variations in Test Coil Impedance

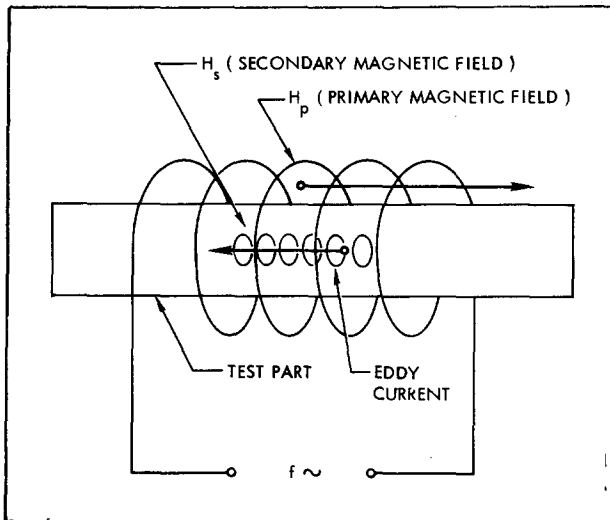


Figure 4-82. Test Part Inserted in Test Coil Indicating Primary and Secondary Magnetic Fields

4-126. **CRITERIA.** The acceptance level of eddy current equipment can in principle only be determined electronically. However, the possibility exists to test the instrument in a practical test by measuring the differences in impedance between known samples. The instruments are calibrated according to the procedures given by the individual manufacturer. Follow these instructions carefully.

4-127. **POSSIBLE AND IMPOSSIBLE WELD INSPECTION WITH EDDY CURRENTS.** It is impossible to detect defects with eddy currents in welds when the material thickness exceeds the depth of penetration. In addition, the roughness of the weld bead will interfere with a stable reading while the metallurgical changes in the material, due to welding will also make this detection impossible. At present it was not feasible to determine with eddy currents the presence of carbide precipitation. Ultrasonic inspection provides a possibility for the detections of carbide precipitation.

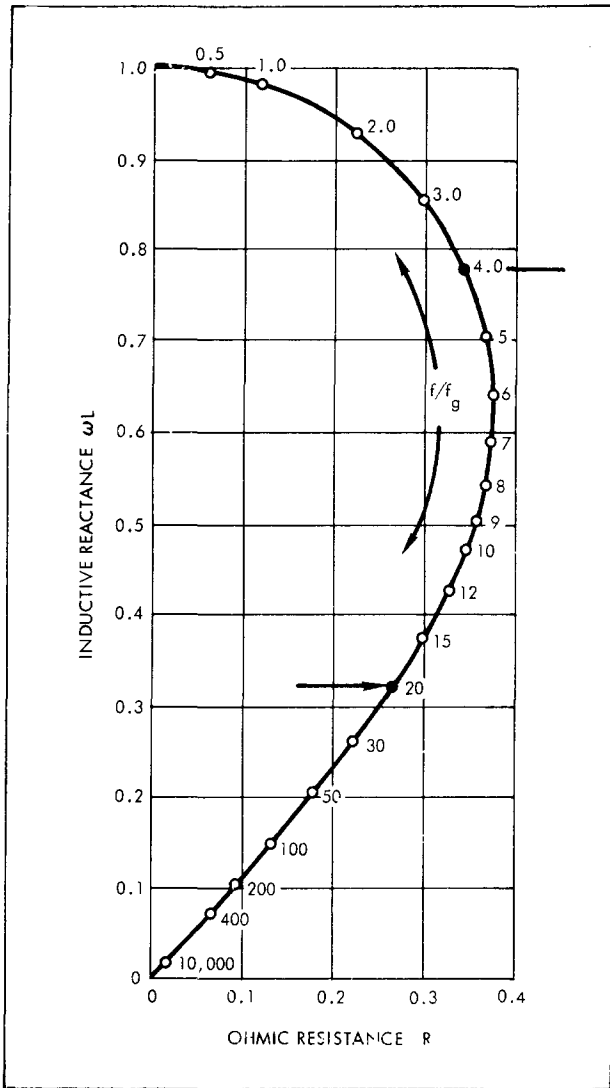


Figure 4-84. Variations in Test Coil Impedance

4-128. PRINCIPLES OF OPERATION-INSTRUMENT MAGNATEST ED-300: (See figure 4-88). The ED-300 instrument is a low-frequency power-loss measuring instrument for ferro-magnetic metals. The operating frequency of 360 cycles per second was selected to provide for reasonably effective penetration, well below the surface scale, oxides, etc., and also of sufficient power to overcome the magnetic inertia (domain mobility threshold) for most engineering steels. Also, the frequency must be as high as possible to keep the probe to a practical physical size, and again, be not too high and exceed the magnetic inertia (domain mobility) limit of engineering steels. Measurements made with the ED-300 may, in general, be considered as power-loss measurements, or measurements primarily due to eddy current and hysteresis losses.

4-129. When an alternating current is made to flow through a coil held in proximity to a ferromagnetic

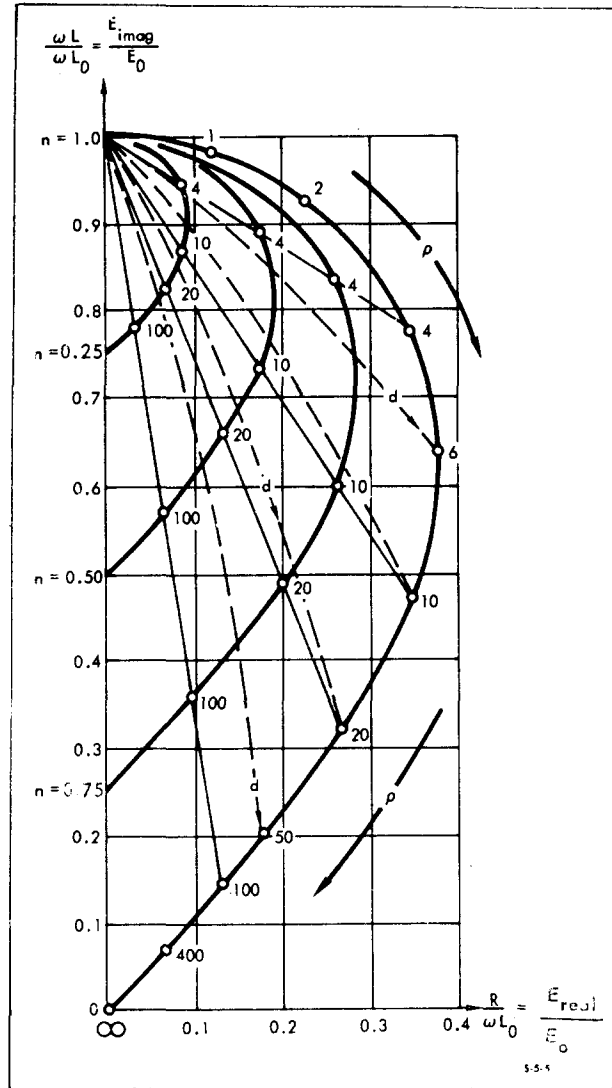


Figure 4-85. Test Coil Impedance Curves for Various Values of Fill Factor

metal, alternating magnetic fields are induced in the metal. These fields, in turn, will induce circular counter-currents (eddy currents) within the metal. The respective counter field developed by eddy currents will oppose the applied field with a magnitude and phase dependent on the resistivity and permeability of the metal. Both of these characteristics vary with analysis and structure; permeability being by far the greatest affected. The losses associated with each cannot be measured independently of each other, using alternating magnetic field techniques, but their sum can be indicated on the ED-300 meter.

4-130. OPERATING INSTRUCTIONS FOR ED-300 INSTRUMENT. Front panel controls for the ED-300 instrument are as follows:

- a. BALANCE CONTROL - To position meter pointer.

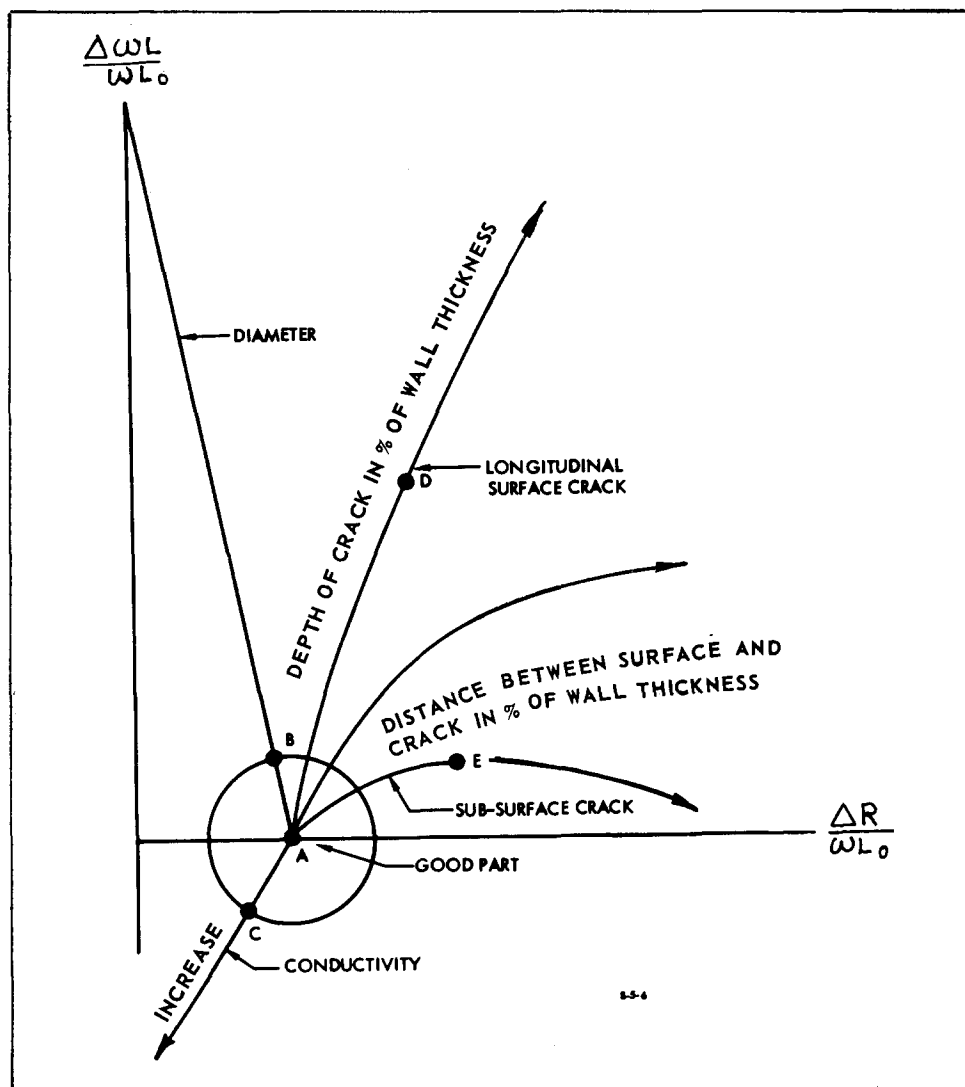


Figure 4-86. Impedance Changes Caused by Surface and Subsurface Defects

b. COMPENSATOR CONTROL - Enables compensation to various types of surface conditions.

c. SENS-CAL CONTROL - Controls instrument sensitivity and permits instrument calibration.

4-131. Operate the ED-300 instrument as follows:

a. Connect the line cord to a 115 volt, 60 cycle power source.

b. Connect the probe or coil and cable to the unit.

c. Turn power switch to ON. The pilot lamp will light, indicating the unit is in operation.

d. Turn the SENS-CAL control to MAX-SENS position.

e. Allow at least one-quarter hour initial warmup to permit tubes and other components to reach stable operating conditions.

f. Place the probe ball tip on the surface of the metal to be measured and adjust BALANCE control to position the meter pointer on-scale.

g. Place a small piece of ordinary writing paper between the probe tip and metal surface. Note meter reading difference (if any). If the meter reads lower with the probe on the paper than on the bare metal surface, turn COMPENSATOR control clockwise, repeating test until the meter reads exactly the same with probe on paper and on bare metal.

#### NOTE

The reverse procedure should be followed if the meter reads higher with the probe on the paper than on the bare metal surface. During this compensation adjustment, it may be necessary to use the BALANCE control to keep the meter pointer on-scale.

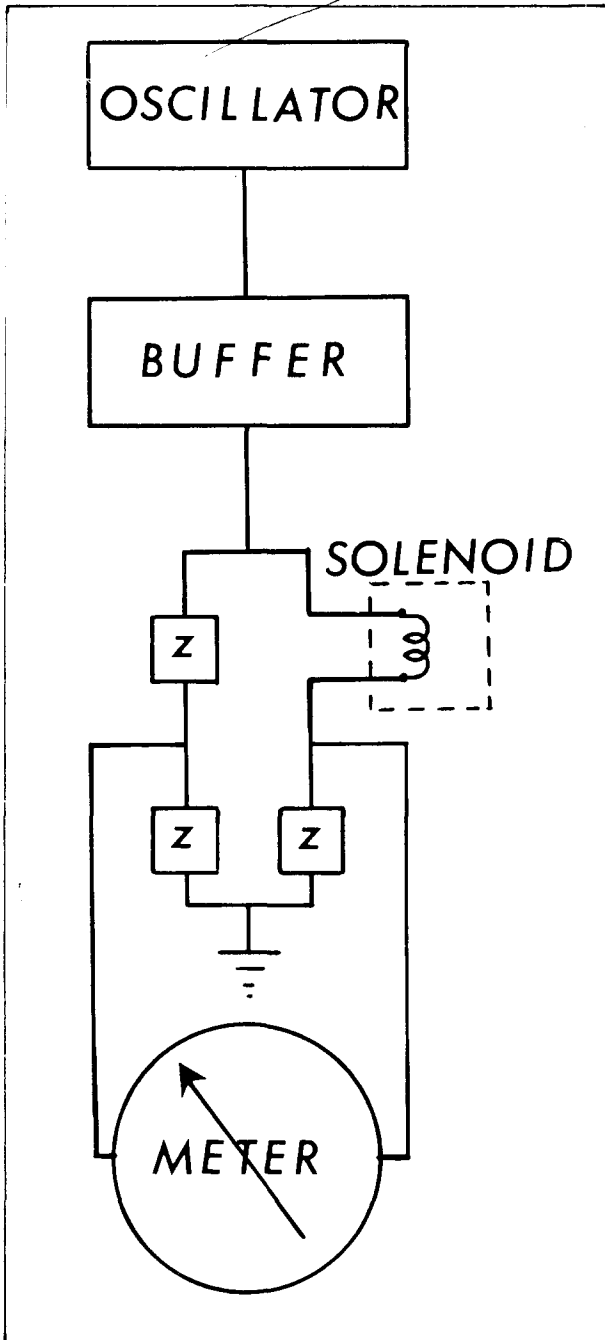


Figure 4-87. Basic Block Diagram for Eddy Current Instrument

4-132. The purpose of the paper-metal compensation adjustment is to simulate a condition known as "intermediate layer" and provide a simple means to adjust the instrument to normal production surface roughness conditions. This type of adjustment and compensation is necessary to obtain the reproducibility of measurement. The ED-300 instrument can also be compensated for surface conditions or varia-

tions without the use of a paper spacer or shim. For example, a ground to as-cast surface compensation can be carried out in the same manner by sliding the probe from ground to cast surface, noting the meter difference and making the necessary compensator control adjustment.

4-133. CALIBRATION PROCEDURE FOR ED-300 INSTRUMENT. For the purpose of taking and permanently recording data and comparing measurements between different groups of samples, or on other ED-300 instruments, the following calibration procedure can be followed:

a. Follow operating instructions outlined in paragraph 4-130. The only difference in the metal surface or metal referred to in paragraph 4-130, subparagraphs f and g, is the ED-300 calibration sample marked "MED".

b. Place the probe on calibration sample marked "LO" and adjust the BALANCE control so that the meter reads the stamped value.

c. Place the probe on sample marked "HI"; the meter will read considerably higher than the value stamped on this sample. Adjust SENS-CAL control until meter reads the value stamped on this sample.

d. Repeat steps b and c, using both the BALANCE and SENS-CAL controls to obtain the meter readings stamped on the "HI" and "LO" calibration sample. Placing the probe on the "MED" sample should provide the meter reading stamped on it. The instrument is now calibrated and although the sensitivity is greatly attenuated, most engineering steels will fall somewhere within the limits of the meter scale providing a reference measurement for permanent data recording or comparison purposes. Units of measurement are read directly from the meter scale 0-500.

4-134. There is a limit or minimum sample size for which the units are comparable and valid. This size is approximated by the calibration samples. The meter scale of the ED-300 instrument is calibrated in units of 0 to 500 microamperes. This is a basic meter movement and the units have a relative value only. As explained in paragraph 4-128, the instrumentation measures the power losses in a metal under a probe by the induction of a 360-cycle field in the metal. Under these conditions, the losses are attributed mainly to hysteresis, and to a secondary degree, to resistivity. Since there is no absolute units of such measurements under these conditions, and for the necessity of permanent data recording, standardization between units and exchange of application information, the ED-300 meter scale henceforth will be referred to as E.C. units.

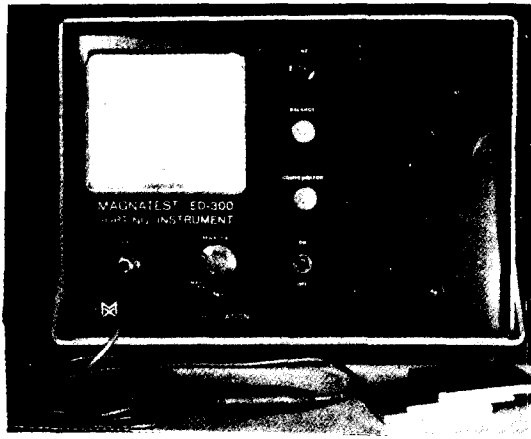


Figure 4-88. ED-300 Instrument

4-135. Paragraph 4-133 describes the calibration sample and steps necessary to accomplish calibration. Once the unit has been calibrated, an appreciable amount of valuable information of a general nature can be obtained from the relationship of units to structural and chemical differences in a ferromagnetic metal. Although the E.C. units have no direct relationship to any other type of absolute unit of measurement, a certain "loose" relationship does exist and can be stated as follows: "The higher the E.C. unit, the higher the permeability."

4-136. DETERMINATION OF HEAT AFFECTED ZONE IN FERROMAGNETIC MATERIAL. To determine the heat affected zone in ferromagnetic material, proceed as follows:

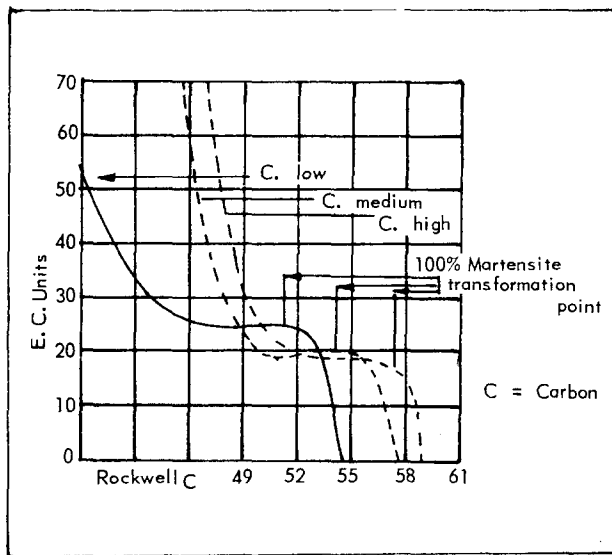


Figure 4-89. Relative Eddy Current Values Versus Hardness

- a. Calibrate equipment as described in paragraph 4-133.
- b. Place probe on material at least 12 inches away from any welded area.
- c. Move the probe slowly towards the welded area and note the point where read-out indication changes. This change will be relatively slow and in many cases starts close to the weld.

The eddy current units provide other rule-of-thumb relationships between chemical and structural differences associated with ferromagnetic materials. The graphs, figures 4-89 and 4-90, will provide a general idea of how the units and the more common variables are related.

As the carbon contents will decrease in the heat affected zone, the meter reading will be higher as is indicated in the graphs in figure 4-90.

4-137. EDDY CURRENT INSPECTION OF STAINLESS STEEL AND OTHER LOW CONDUCTIVITY NON-MAGNETIC MATERIALS USING ED-500 INSTRUMENT. (See figure 4-91.)

4-138. Operate the ED-500 instrument as follows:

- a. Connect the probe to the ED-500 instrument. Turn the instrument on and allow at least 15 minutes to warm up.
- b. "Frequency Control" setting required:

PERCENT I.A.C.S.	FREQUENCY CONTROL SETTING
Up to 15	2 or 1 (100 - 120 KC)

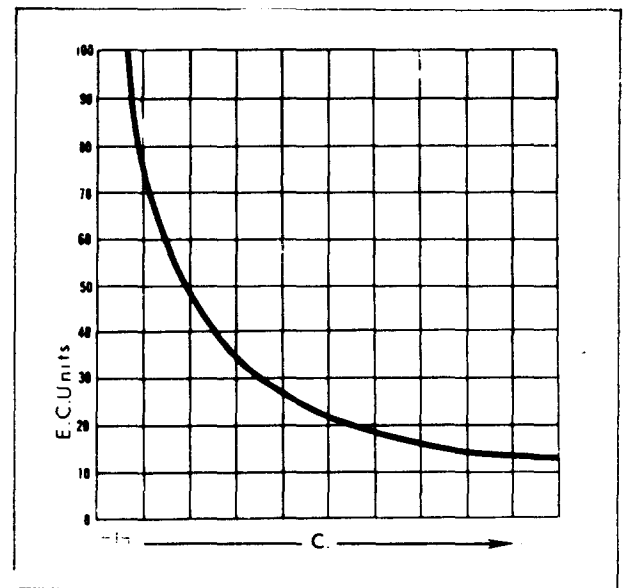


Figure 4-90. Relative Eddy Current Values Versus Carbon Content



Figure 4-91. FD-500 Instrument

c. Set **FREQUENCY CONTROL** to the desired position. Turn **SENSITIVITY CONTROL** to **MAX**.

d. Place the probe on a mid-range sample of a metal to be sorted and adjust **BALANCE CONTROL** until the meter reads mid-range or 250 microamperes. Should the meter deflect down-scale as the probe is placed on the sample, reduce **FREQUENCY CONTROL** setting by one position.

e. Place a single sheet of ordinary writing paper (0.002- to 0.004-inch thick) between the probe and sample, and note the amount of deviation of the meter from the initial reading without the paper.

f. By means of **BALANCE** and **LIFTOFF** controls only, endeavor to maintain a meter reading of 250 microamperes for the probe on the bare sample and through the paper shim. The two controls interact and a combination of the two will give the desired results, i.e. when the meter is adjusted to read 250 microamperes on a bare sample, a paper shim between the probe and the sample may cause the meter to read, for example 350. By adjusting **LIFTOFF** control until the meter again reads 250, remove the paper shim and with the probe now on the bare surface, return the meter to 250 microamperes by means of the **BALANCE CONTROL**.

g. Repeat this procedure several times. The difference between the meter reading on the bare sample and through a paper shim should be narrowed to practically nothing by repeating the procedure.

In fact, a point can be reached whereby the intermediate layer compensation can be accomplished up to 0.01 inches of paper shims. Should the meter reading differences increase during these adjustments, reverse the procedure. That is, if the **LIFTOFF** control was used to bring the meter pointer down-scale to 250, use the two controls for opposite purposes.

h. If the intermediate layer compensation cannot be readily obtained and the **LIFTOFF ADJUST** control is in the maximum clockwise position, reduce the **FREQUENCY CONTROL** setting one position and set the **LIFTOFF** control to its extreme counterclockwise position.

i. Repeat intermediate layer adjustments.

j. When the instrument has been properly adjusted at maximum sensitivity, the spread on the meter can be reduced by adjusting the **SENSITIVITY CONTROL** until the limits of the range are well within the limits of the meter movement.

#### 4-139. DETERMINATION OF HEAT EFFECTED ZONE IN STAINLESS STEEL AND OTHER LOW CONDUCTIVITY NON-MAGNETIC MATERIALS.

Calibrate equipment as described in paragraph 4-133, and operate as follows:

a. Place probe on material at least 12 inches away from any welded area.

b. Move the probe slowly towards the welded area and note the point where the read-out indication changes. This change will be relatively slow and in many cases starts close to the weld.

#### 4-140. DETERMINATION OF HEAT AFFECTED ZONE IN NON-MAGNETIC MATERIALS WITH A CONDUCTIVITY OF OVER 10 PERCENT I.A.C.S. (INTERNATIONAL ANNEALED COPPER STANDARD). USING FM-120 INSTRUMENT. (See figure 4-92).

4-141. CALIBRATION PROCEDURE FOR FM-120 INSTRUMENT. Calibrate the FM-120 instrument before use. When operated for long periods of time, calibration should be checked at frequent intervals. Each instrument is furnished with two calibration samples. These samples have the conductivity values stamped on them. The following adjustments should be made when the instrument is received and prior to each test period.

a. With switch turned off, adjust the meter mechanically to zero by turning the small screw directly below the meter face.

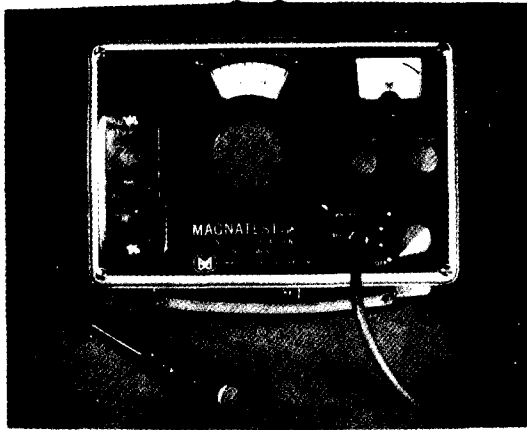


Figure 4-92. FM-120 Instrument

b. Turn the switch to position B. No warm up period is required. Position B connects battery test circuit. If the batteries are satisfactory, the meter needle will swing to the right and stop within the red zone. If the needle does not reach the red zone, batteries must be replaced.

c. Turn the switch to position 1; the lower sensitivity. This setting can be used for measurements when only approximate conductivity readings are desired and can also be used during calibration.

#### 4-142. CALIBRATION AT HIGH END OF DIAL.

a. Set the index on the conductivity dial to the red line at the high end of the scale.

b. Press the probe firmly against the high conductivity calibration sample.

c. Adjust the CAL-HIGH control knob so that the meter reads zero.

#### 4-143. CALIBRATION AT THE LOW END OF DIAL.

a. Set the index of the conductivity dial at the red mark at the low end of the scale.

b. Press the probe firmly against the low conductivity calibration sample.

c. Adjust the CAL-LOW knob so that the meter reads zero.

### NOTE

Because of inter-action in the circuit, steps outlined in paragraphs 4-132 and 4-133 may have to be repeated so that the meter reads zero for both the high and low calibrations. Turn the switch to position 2 (high sensitivity) and repeat steps outlined in paragraphs 4-132 and 4-133 for the final calibration.

4-144. ACCURACY IN MEASUREMENTS. For obtaining the most accurate measurements, the instrument, calibration samples, and test part must be stabilized at the same temperature. The accuracy is not decreased by temperature variations, provided the unit is calibrated at ambient temperature. When tests are performed, the probe must be firmly pressed against a flat surface with a minimum diameter of one-half inch. Any such flat surface of non-magnetic sheet, stamped or cast parts may be used for the conductivity measurement. If the radius of curvature of a concave surface is less than 20 inches, the accuracy of these measurements will be reduced. On convex surfaces, a minimum radius of curvature of 4 inches can be tolerated. Measurements are independent of thickness, provided the material is thicker than the depth of penetration of the eddy currents. The depth of penetration is 0.030-inch for materials having a conductivity of 98 percent I.A.C.S., and 0.080-inch for materials having a conductivity of 12 percent I.A.C.S.

4-145. ABSOLUTE MEASUREMENTS. When measuring parts to obtain the absolute value of electrical conductivity, hold probe firmly against the material to be tested. Rotate the conductivity dial until meter reads zero. The conductivity is then read directly behind the hairline on the conductivity dial.

4-146. RELATIVE MEASUREMENTS. To determine the heat affected zone, the absolute value of conductivity is not required. All that must be known is whether the conductivity is greater or less than a given value, or that it lies between certain limits. Also, adjustment of the dial to zero in each case may be time consuming. In such cases, two samples are selected having conductivities at upper and lower limits. The conductivity dial and the switch are then adjusted so that these samples produce a positive and negative deflection on the front panel meter. A greater needle swing (or sensitivity) will be noted for small variations in conductivity when the switch is in position 2, than when the switch is in position 1. Production parts can now be tested without adjusting the main dial; the deflection of the meter indicating the relative conductivity or extent of the heat affected zone. On round stock having a radius of curvature less than four inches, a jig should be used to assure that the probe is placed in the same position on each piece.

4-147. The instruments stated in the paragraphs 4-128 through 4-133, cover the full range of materials for determination of the heat affected zone. It is also possible to detect the presence of surface cracks with this instrumentation. The indication will reflect a sudden decrease in conductivity and as such it can be differentiated from the variations caused by the heat affected zone, which are relatively slow. In conclusion, it can be stated that the value of eddy current techniques in the inspection of weldments is limited to:

a. Relative measurements to determine extent of heat affected zone.

b. Detection of cracks in parent material.





## SECTION V

### WELDING PROCEDURE SPECIFICATIONS FOR SHEET, PLATE, AND STRUCTURAL SHAPES

#### 5-1. GENERAL.

5-2. This section presents preparation and welding of sheet, plate, and structural shapes for the shielded metal arc welding process, using covered welding electrode.

#### 5-3. REQUIREMENTS.

5-4. Preparation and welding of sheet, plate, and structural shapes shall be performed in accordance with the specific requirements of this Section and the applicable requirements presented in Section III.

#### 5-5. PREPARATION OF BASE METAL.

### WARNING

To prevent injury, impact-type goggles or face shield and approved safety equipment shall be worn by personnel when engaged in machining, grinding, and flame cutting operations.

5-6. The edges or surfaces of parts to be joined by welding shall be prepared by machining, grinding, flame cutting, or other approved mechanical methods. Prior to welding, all edges and surfaces shall be thoroughly cleaned of all remaining oxides, oil, grease, paint, dirt, or other foreign matter.

5-7. Grinding wheels used on material specification American Society for Testing Materials (ASTM) A 353-58 (9% nickel steel) shall be of alumina-oxide or equal, wire brushes used for cleaning shall be stainless steel. Grinding wheels and wire brushes shall not have been previously used on carbon steels.

#### 5-8. PLATE POSITIONS.

5-9. The plate positions applicable for these welding procedure specifications are presented in Figures 5-1 through 5-3.

#### 5-10. BEVELS FOR SHEET, PLATE, AND STRUCTURAL SHAPES.

5-11. Welding edges of sheet, plate, and structural shapes to be welded with a root opening shall be beveled at  $37\text{-}1/2$  ( $\pm 2\text{-}1/2$ )-degree angle leaving a  $1/16$  ( $\pm 1/32$ )-inch root face land (see Figure 5-4).

5-12. Welding edges of sheet, plate, and structural shapes requiring the lands to rest on a backing structure or a flat bar butt strap, shall be beveled at a  $30$  ( $+2\text{-}1/2$ ,  $-0$ )-degree angle, leaving a  $3/16$  ( $\pm 1/32$ ,  $-0$ )-inch root face land (see Figure 5-5).

#### 5-13. FITTING UP AND TACK WELDING.

5-14. Weld joints which require a root opening, shall have a separation between lands or welding edges of  $3/32$  ( $+0$ ,  $-1/32$ )-inch for the full length of the joint (see Figure 5-4).

5-15. Weld joints in which the lands rest on a backing structure or a flat bar butt strap, shall have a separation between lands or welding edges of  $3/16$  ( $+0$ ,  $-1/32$ )-inch for the full length of the joint (see Figure 5-5).

5-16. The thickness of lands or welding edges may be varied to ensure complete penetration of the first pass or root weld deposit.

5-17. Abutting edges of sheet, plate, and structural shapes at longitudinal joints shall not, after being welded, have an offset from each other at any point in excess of  $1/16$ -inch, or one-fifth of the nominal plate thickness at the joint, whichever is less.

5-18. The separation between faying surfaces (see Figure 5-5) of butt joints which rest on a backing structure, and lap joints, shall be as close as is practicable. Under no conditions shall the separation between faying surfaces of contact members exceed  $1/16$ -inch at any point.

#### 5-19. OTHER WELD JOINTS.

5-20. Weld joints not specified in this technical order shall be prepared and welded as directed by the Design Engineer.

#### 5-21. REBUILDING JOINTS.

5-22. Welding edges of joints shall not be rebuilt or repaired prior to welding without specific approval of the Design Engineer. Repair or rebuilding of joints shall be accomplished as directed by the Design Engineer.

5-23. In event operating personnel have a doubt as to the nature of the joint or its preparation, the Design Engineer shall be consulted, and his approval obtained before proceeding with any further preparation or welding of the joint in question.

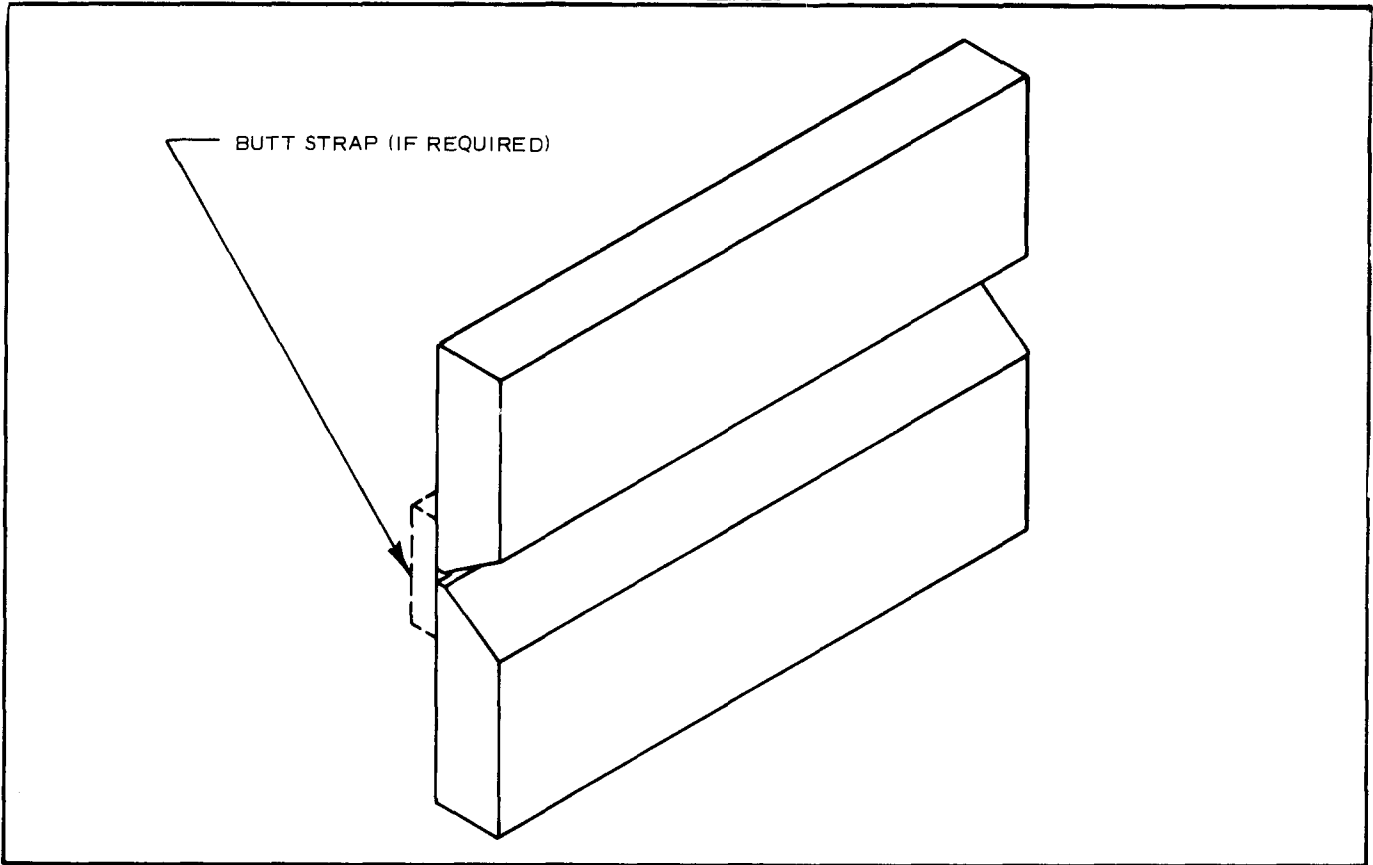


Figure 5-1. PLATE AND GROOVE IN HORIZONTAL POSITION (2G)

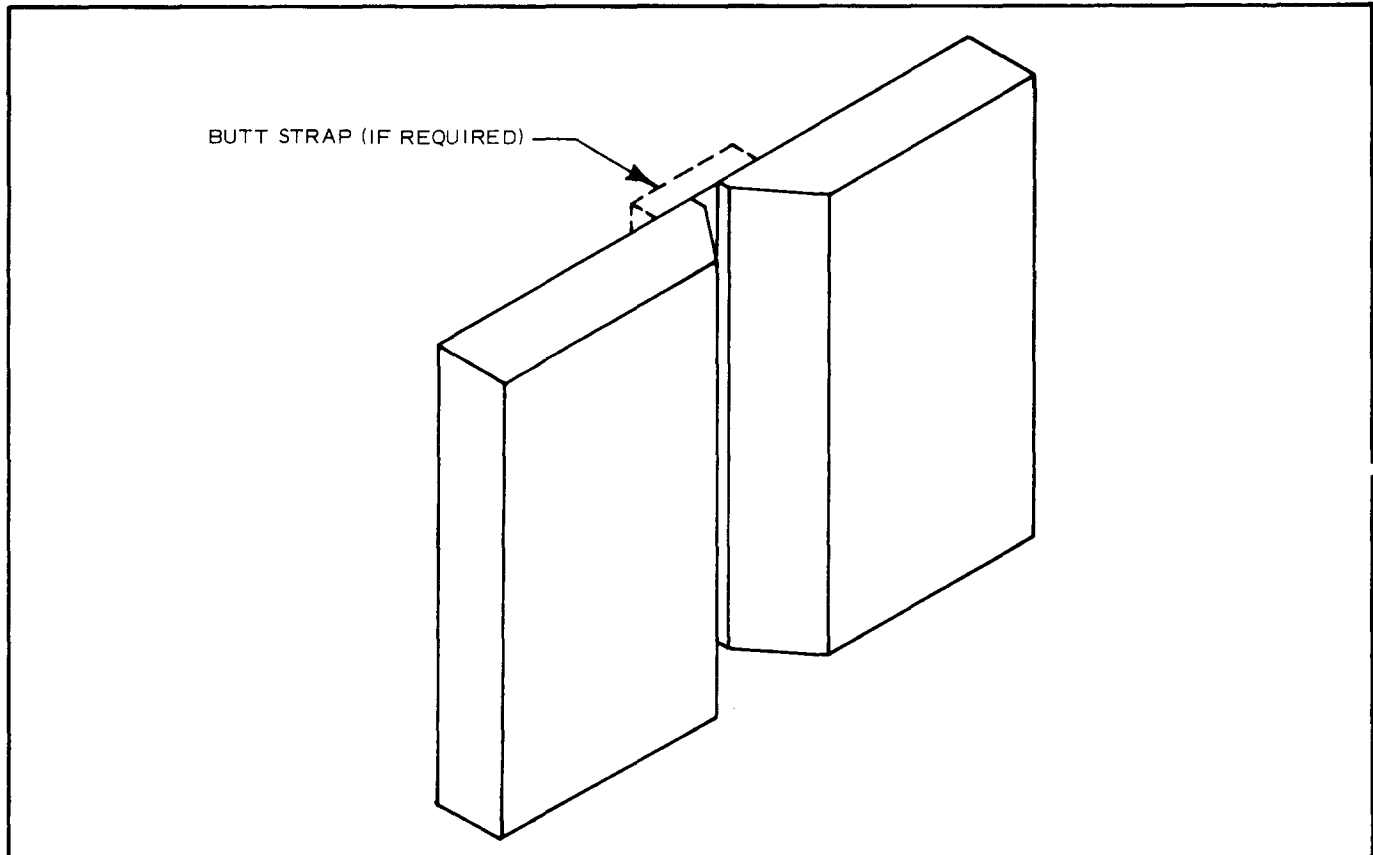


Figure 5-2. PLATE AND GROOVE IN VERTICAL POSITION (3G)

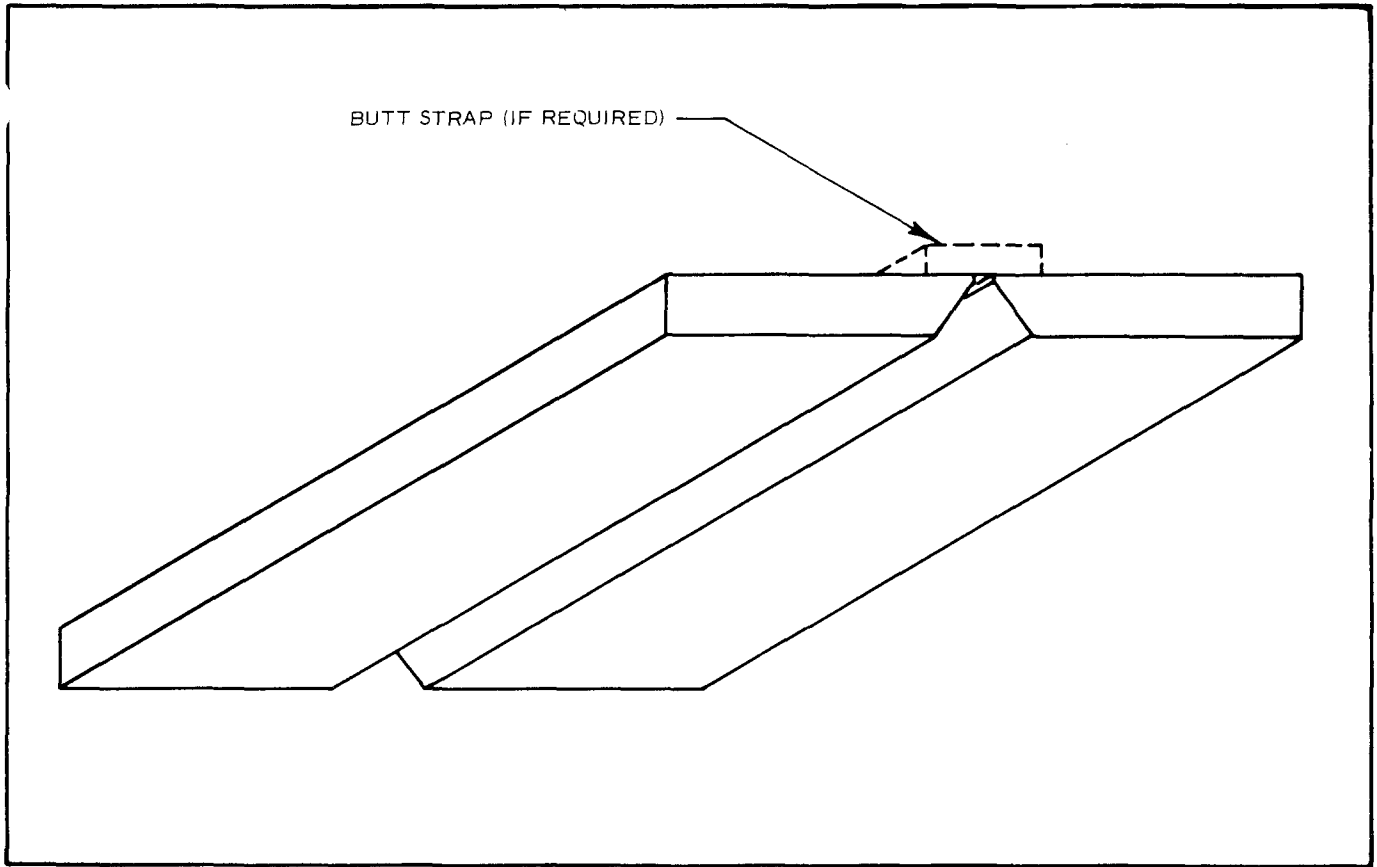


Figure 5-3. PLATE AND GROOVE IN OVERHEAD POSITION (4G)

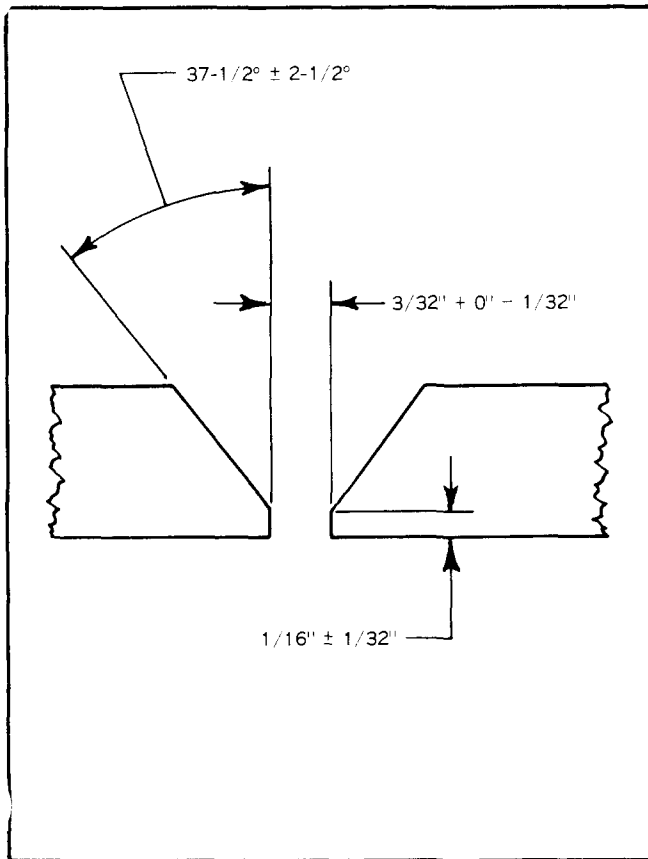


Figure 5-4. DIMENSIONS FOR ROOT OPENING

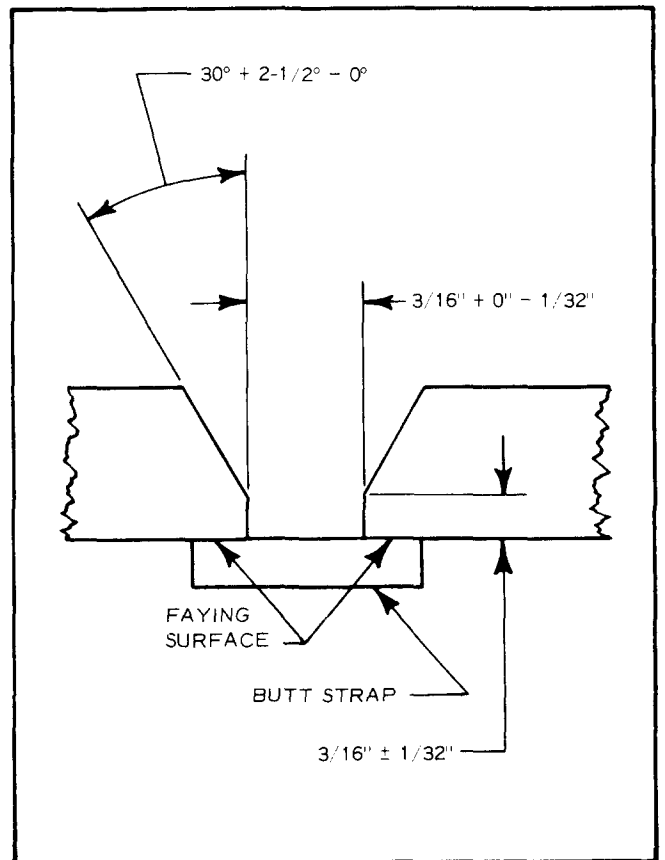


Figure 5-5. DIMENSIONS FOR ROOT OPENING WITH BUTT STRAP.

5-24. HOLDING DEVICES.

**WARNING**

To prevent injury to personnel and damage to equipment, precautions shall be taken to ensure that holding devices and supporting structures are adequate and secure throughout the welding operation.

5-25. All parts to be joined by welding shall be securely held in correct position by jigs, clamps, lugs, saddles, other suitable holding devices, or by tack welds.

5-26. Holding devices shall be adequate to maintain alignment of all parts throughout the entire welding operation.

5-27. Temporary lugs, saddles, holding devices, etc., welded to base metal while fitting up parts, shall be of like material, using the specified welding process and electrodes; under no conditions shall dissimilar metal or welding processes be used for this purpose without specific approval of the Design Engineer.

5-28. Holding devices used to secure parts in correct position during the welding operation, shall be properly placed and fitted in such manner that normal expansion and contraction of the parts being joined shall not be restricted, and thereby induce such high stresses that cracking of the material will result.

5-29. TACK WELDS.

5-30. Tack welds shall be of the same quality, and made by the same procedure as the completed weld, or shall be removed prior to welding at the point where the tack weld is located.

5-31. FIXED POSITION WELDING.

5-32. Orientation of weld joints shall be in accordance with Paragraph 2-52. Fixed position welding shall be accomplished in such manner that weld metal is deposited from the horizontal, vertical, or overhead fixed positions (see Figures 5-1 through 5-3); under no conditions shall the weld joint orientation be changed while welding is in progress.

5-33. Welding shall be started at the bottom of the vertical joint and progress upward to the top of the joint; under no conditions shall the welding progress in a downward direction.

5-4

5-34. WELDING MACHINES.

**WARNING**

To prevent injury to personnel, frames of all welding machines shall be thoroughly grounded to prevent electrical shock. All leads to the electrode, and ground connections of the work, shall be of sufficient size to carry the electrical current with a minimum of resistance. Secure electrical connections shall be maintained between the machine and the work.

5-35. Welding machines shall be standard equipment designed for continuous operation, with the capability to provide a constant supply of electrical current sufficient in amount, and of proper voltage, to maintain the welding arc in a stabilized condition throughout the welding operation.

5-36. Welding machines shall not be operated at over 70% of the rated capacity as indicated on the manufacturer's nameplate attached to the welding machine.

5-37. ELECTRICAL CHARACTERISTICS.

5-38. The welding current shall conform with respect to both voltage and amperage (and polarity, when direct current is used) as recommended by the manufacturer of the weld metal being used.

5-39. PREHEAT TREATMENT.

5-40. When the temperature of the base metal is less than 70° F, the base metal shall be preheated to a minimum temperature of 70° F (or at least warm to the touch) for a distance of not less than three inches on each side of the joint before welding is started. Under no conditions shall the temperature of the base metal and/or weld deposits be less than 70° F while welding is in progress, or before the weldment is completed. This shall be considered a requirement for all materials. The appropriate preheat treatment for sheet, plate, and structural shapes is presented in Section VI.

5-41. Preheat treatment for a particular welding procedure, or specific type of base metal, shall be performed in accordance with the certified qualification procedure test data for each respective welding procedure (refer to Paragraphs 3-106 through 3-117), or as directed by the Design Engineer.

5-42. Welding shall not be performed when the metal surfaces are wet from rain or snow, or when rain or snow is falling on the metal surfaces to be welded; or during periods of excessive air currents unless the operator and the work are properly protected with suitable shelter.

**5-43. ELECTRODES.**

5-44. The care and method of handling and storing welding electrodes is of the utmost importance. Electrodes with low-hydrogen type coatings such as ASTM A 233-58T, E7016-E7-18; ASTM A 316-58T, E7016-E7018, E8016-C2-E8018-C2, E10016-D2-E10018-D2, E11016-E11018, and E12016-E12018, require special care and treatment to prevent damage to the coatings.

**NOTE**

Information contained in Paragraphs 5-45 through 5-48 are provided as general requirements for storage, handling, and treatment of electrodes. Should a conflict exist between this information and that furnished by the electrode manufacturer, the latter's recommendations shall have precedence.

5-45. Underbead cracking and porosity can be the result of hydrogen gas evolved from electrode coatings. These low-hydrogen type coatings will absorb moisture when exposed to the atmosphere and may pick up sufficient moisture content to render them no longer useful as low-hydrogen type electrodes. Therefore, it is absolutely essential that all electrodes remain in the original containers and are properly stored in a drying and holding oven or baking oven as required (refer to Paragraphs 5-46 or 5-47 as applicable) until needed for immediate use.

**CAUTION**

Electrodes shall not be stored in a drying and holding oven at temperatures greater 300° F. Overexposure to temperatures in excess of 300° F will cause deterioration of electrode coatings.

5-46. If the electrodes are packed in an undamaged air-tight metal container, they shall be placed in a ventilated drying and holding oven with a holding temperature range of 250° F to 300° F.

**CAUTION**

Electrodes shall not be exposed to temperatures greater than 800° F while in the baking oven. Exposure to temperatures greater than this limitation will result in the electrodes being unfit for use.

5-47. If the electrodes are packed in a container that is not air-tight, or is in one of the cardboard type boxes, the electrodes shall be placed in a baking oven and baked a maximum of one hour at 800° F, then transferred, while still warm, to a drying and holding oven.

5-48. The time period for which electrodes may be exposed to outside air conditions varies with the ambient humidity. Electrodes will not pick up moisture from air having less than 50 percent relative humidity, regardless of the length of exposure time. As the humidity increases above 50 percent, moisture pickup increases proportionately, thereby shortening the safe exposure time. Those geographical areas in which high humidity is prevalent, the maximum exposure time for electrodes shall be four hours, at which time the electrodes shall be returned to the drying and holding ovens.

5-49. Electrodes which have been in physical contact with water or other liquids shall be discarded; baking or other means of moisture removal are not effective.

5-50. When there is a reason to question or doubt as to the moisture content of electrodes, or in cases where problems develop and trouble is encountered in deposition of the weld filler metal, the electrode coatings shall be analyzed for moisture content in accordance with specification MIL-E-22200. Under no conditions shall electrodes be used for welding when the moisture content of the coatings exceed 0.2 percent.

5-51. Users of low-hydrogen type electrodes shall be governed by the following general guides and techniques:

1. Electrodes larger than 3/16-inch in diameter shall not be used (1/8-inch or 5/32-inch are the preferred sizes). The following shall determine the electrode size to be used:
  - a. The thickness requirements of the weld material.
  - a. Joint design.
  - c. Bead size for each pass of weld deposit.
  - d. Number of passes or beads required to complete the weld joint.
  - e. Maximum allowable electrical current or heat input for a specific welding operation.
2. A moderate and controlled preheat shall be used.
3. A welding current compatible with the size and type of the selected electrode shall be used to avoid overheating (current ranges for each size of electrode shall be as recommended by the electrode manufacturer).

4. A string bead technique shall be used (a string bead is a type of weld without appreciable oscillation).

5. A wide weave or wash technique shall not be used. A wide weave or excessive oscillation of the electrode will result in a wide and thin weld deposit, which is subject to cracking and subsequent failure.

#### 5-52. INTERPASS TEMPERATURES.

5-53. Interpass temperatures for welding sheet, plate, and structural shapes shall be in accordance with the specified preheat temperature as recorded in the certified qualification procedure test data for each respective welding procedure. Each complete pass of weld metal deposit shall be allowed to cool to the specified maximum preheat temperature before additional weld metal is added.

5-54. In cases where a preheat treatment is not required for a specific material or welding procedure, the interpass temperature shall not exceed 300° F at the area immediately adjacent to the point at which the succeeding pass or bead of weld metal is to be made. Areas remote from this point may exceed the specified temperature, but the temperature shall not be greater than 300° F at the time weld deposits are made at these locations.

5-55. All materials shall be allowed to cool to the specified interpass temperature by natural means; the use of air, water, or other liquids for cooling is not permitted.

#### 5-56. SEQUENCE.

5-57. The welding sequence shall be such as to avoid needless distortion of the parts. A backstep or wandering sequence shall be used where necessary to prevent excessive stresses in the base materials and/or weld metal deposits. The Welding Supervisor or Design Engineer may at any time direct the sequence of welding for a particular fabrication (refer to Paragraphs 3-188 through 3-192 and Paragraphs 3-124 through 3-129).

#### 5-58. WELD METAL DEPOSIT.

5-59. The welding technique and manner of depositing the weld metal shall be such that there will be no undercutting on the sidewalls of the welding groove or adjoining base metals. Each bead or layer of deposited weld metal shall be uniform, and shall blend smoothly with the base metal. Cracks or defects of any type or size that appear in any bead or layer of weld metal deposit shall be removed before starting the next successive bead or layer.

#### 5-60. ROOT WELD DEPOSITS.

5-61. All first pass, or root weld deposits, shall have full penetration for the full length of the joint, and

shall be started midway between previously placed tack welds; when welding over tack welds, the welder shall slow the rate of travel sufficiently to ensure complete fusion of all tack weld metal.

5-62. After every interruption of the arc, (except at the completion of a pass or a bead) the arc shall be restarted ahead of the previous deposit, and then moved back to fill the crater. This technique will ensure complete filling of the crater, complete fusion between the new and old deposits and the base metal at the point of junction, and complete resultant continuity of weld.

#### 5-63. MULTI-LAYER WELDING.

5-64. When multi-layer welding is employed, each layer shall be not more than 1/8-inch thick, and shall be uniform in thickness, with no evidence of excessive metal buildup at any point. This may be accomplished by use of the backstep technique. The several layers shall be made successively, completing each layer before starting the next.

5-65. Before welding over previously deposited weld metal, all traces of slag, weld spatter, oxides, metal ejected from the arc, and foreign matter shall be removed by mechanical means from the weld deposit, and the weld deposit and adjoining base metal shall be wire-brushed until thoroughly clean. This shall apply not only to successive beads, but also to successive layers and to the overlapping area wherever a junction is made when starting a new bead or layer. All materials must be bright and clean throughout the welding operation.

#### 5-66. BUTT WELDS.

5-67. Reinforcement of butt welds shall be not less than 1/16-inch and shall be built up uniformly from the surface of the base metal to a maximum of 3/32-inch at the center of weld joint, and shall blend smoothly and gradually with the base metal.

5-68. The width of completed butt welds shall not exceed the total dimensions specified by design of the joint for the included angle of bevels, plus 1/8-inch. Finished weld contours shall be uniform and free from depressions, undercuts, or other surface defects. All slag, weld spatter, undue roughness, and foreign matter shall be removed from the surfaces of weld joints and adjoining base materials. Completed weldments shall have bright, clean surfaces.

#### 5-69. PEENING.

5-70. Peening of weld metal and/or base metal is not permissible for any purpose without specific approval and as directed by the Design Engineer. Hot or cold peening of weld metal deposits to conceal the presence of cracks or other defects is not permitted (refer to Paragraphs 3-131 through 3-134, and Paragraph 3-206).

**5-71. POSTHEATING.**

5-72. Postheating of weld metal deposits and/or base metals to straighten or align a weldment is not permitted.

5-73. In cases where postheating and/or stress relieving procedures are required for a specific type or combination of weld and base metals, or for service requirements, they shall be performed in accordance with the certified qualification procedure test data for each respective welding procedure, or as directed by the Design Engineer.

**5-74. WELD INSPECTION AND QUALITY CONTROL.**

5-75. The quality of all welding for sheet, plate, and structural shapes shall be in accordance with the specific requirements of this Section, and the applicable parts of the Engineer's quality requirements (refer to Paragraphs 3-140 through 3-143).

**5-76. RADIOGRAPHIC EXAMINATION.**

5-77. Welded joints which require radiographic examination shall be prepared in accordance with the stated requirements presented in Paragraph 3-207. Preparation of weld joints shall afford the most favorable conditions for obtaining radiographic films of good quality.

**5-78. DETAILED PROCEDURES.**

5-79. The detailed procedures for which the instructions and specifications are provided in this Section, are depicted in Figure 5-6.

**5-80. PROCEDURES AND TEST DATA.**

5-81. The certified procedures and test data for the detailed procedures are presented in Figures 5-7 through 5-18.

PROC. SPEC. NO.	MATERIAL SPEC.	TYPE MATERIAL	SIZE	TYPE JOINT	BUTT STRAP	FIXED POSITION	THICKNESS QUALIFIED	FILLER METAL SPEC.	PROCESS
1	ASTM A 242-60	None	12" x 10" x 3/8"	Butt/Root Opening	None	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM A-316-58T; AWS E-7018	Manual Metal Arc
2	ASTM A 242-60	None	12" x 10" x 3/8"	Butt/Root Opening	12" x 1" x 1/4"	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM A-316-58T; AWS E-7018	Manual Metal Arc
3	ASTM A 302-56	Grade "B"	12" x 10" x 1/2"	Butt/Root Opening	None	*ASME 2G-3G-4G	3/16 to 1 in.	ASTM 316-58T; AWS E7018-A1	Manual Metal Arc
4	ASTM A 302-56	Grade "B"	12" x 10" x 1/2"	Butt/Root Opening	12" x 1" x 1/4"	*ASME 2G-3G-4G	3/16 to 1 in.	ASTM 316-58T; AWS E7018-A1	Manual Metal Arc
5	ASTM A 212-61T	Grade "B"	12" x 10" x 3/8"	Butt/Root Opening	None	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM 233-58T; AWS E-7018	Manual Metal Arc
6	ASTM A 212-61T	Grade "B"	12" x 10" x 3/8"	Butt/Root Opening	12" x 1" x 1/4"	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM 233-58T; AWS E-7018	Manual Metal Arc
7	ASTM A 353-58	(9% Ni) Grade "B"	10" x 30" x 5/16"	Butt/Root Opening	None	*ASME 2G-3G-4G	1/16 to 5/8 in.	MIL-E-22200/3A Amend #1; MIL-E8N12; ASTM B295-54T	Manual Metal Arc
8	ASTM A 353-58	(9% Ni) Grade "B"	10" x 30" x 5/16"	Butt/Root Opening	12" x 1" x 1/4"	*ASME 2G-3G-4G	1/16 to 5/8 in.	MIL-E-22200/3A Amend #1; MIL-E8N12; ASTM B295-54T	Manual Metal Arc

\*One Complete Test Weld for Each Fixed Position

Figure 5-6. Detailed Welding Procedures (Sheet 1 of 2),



PROC. SPEC. NO.	MATERIAL SPEC.	TYPE MATERIAL	SIZE	TYPE JOINT	BUTT STRAP	FIXED POSITION	THICKNESS QUALIFIED	FILLER METAL SPEC.	PROCESS
9	ASTM A 203-61	(3.5% Ni) Grade "E"	12" x 10" x 3/8"	Butt/Root Opening	None	*ASMW 2G-3G-4G	1/16 to 3/4 in.	ASTM 316-58T; AWS E-8016-C2	Manual Metal Arc
10	ASTM A 203-61	(3.5% Ni) Grade "E"	12" x 10" x 3/8"	Butt/Root Opening	12" x 1" x 1/4"	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM 316-58T; AWS E-8016-C2	Manual Metal Arc
11	T-1	Type "A"	12" x 10" x 3/8"	Butt/Root Opening	None	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM 316-58T; AWS E-12015G	Manual Metal Arc
12	T-1	Type "A"	12" x 10" x 3/8"	Butt/Root Opening	12" x 1" x 1/4"	*ASME 2G-3G-4G	1/16 to 3/4 in.	ASTM 316-58T; AWS E-12015G	Manual Metal Arc

\*One Complete Test Weld for Each Fixed Position

Figure 5-6. Detailed Welding Procedures (Sheet 2 of 2)

## CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc  
 MATERIAL ASTM A-242-60 WELDED TO Same  
 PLATE THICKNESS 3/8" BACKING STRIP THICKNESS None  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 3/4"  
 FILLER METAL SPECIFICATIONS ASTM A-316-58T; AWS E-7018  
 CHEMICAL ANALYSIS C, 0.12; Mn, 0.9; P, 0.03; S, 0.04; Si, 0.80; Mo, 0.40 to 0.65  
 PREHEAT TREATMENT 2G, 250°F; 3G, 200°F; 4G, 150°F  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8" and 5/32" FOREHAND OR BACKHAND TECHNIQUE Forehand  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Ductilend 70 Mo  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 70,000  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-4	See Fig. 5-4	See Fig. 5-4
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	3	3	4
INTERPASS TEMPERATURE	300° F (max.)	300° F (max.)	300° F (max.)
AMPERES & VOLTS	120-190A; 21-24V	115-180A; 22-24V	100-130A; 22-26V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	16" per hour	18" per hour	16" per hour

## TEST DATA — REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	65,087.0	85,826.0	16	P.M.
	2	67,184.0	85,444.0	21	P.M.
VERTICAL (3G)	1	61,075.0	84,000.0	24	P.M.
	2	68,859.0	84,085.0	23	P.M.
OVERHEAD (4G)	1	67,866.0	82,993.0	20	P.M.
	2	67,763.0	85,860.0	22	P.M.
PARENT METAL(S)	465E2402	67,130.0	85,453.0	31	N.A.

## TEST DATA — GUIDED BEND TEST

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

Figure 5-7. Certification and Test Data — Procedure No. 1

CERTIFIED PROCEDURE			
WELDING PROCESS	Manual Metal Arc		
MATERIAL	ASTM A242-60	WELDED TO	Same
PLATE THICKNESS	3/8"	BACKING STRIP THICKNESS	1/4"
THICKNESS RANGE THIS TEST QUALIFIES	1/16" through 3/4"		
FILLER METAL SPECIFICATIONS	ASTM A-316-58T; AWS E-7018		
CHEMICAL ANALYSIS	C, 0.12; Mn, 0.9; P, 0.03; S, 0.04; Si, 0.80; Mo, 0.40 to 0.65		
HEAT TREATMENT	2G & 3G, 200° F; 4G, 150° F		
FILLER ELECTRODE OR WIRE DIAMETER	1/8" and 5/32"	FOREHAND OR BACKHAND TECHNIQUE	Forehand
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Ductilend 70 Mo		
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	70,000		
STRESS RELIEVING PROCEDURE	None		
POSTHEAT TREATMENT	None		

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-5	See Fig. 5-5	See Fig. 5-5
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	9	4	5
INTERPASS TEMPERATURE	300° F (max.)	300° F (max.)	300° F (max.)
AMPERES & VOLTS	140-190A; 22-26V	120-170A; 20-26V	135-180A; 20-26V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	11" per hour	16" per hour	14" per hour

TEST DATA — REDUCED SECTION TENSILE TEST					
DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	66,334.0	84,615.0	25	P.M.
	2	67,511.0	85,594.0	22	P.M.
VERTICAL (3G)	1	66,062.0	84,444.0	23	P.M.
	2	69,084.0	85,399.0	22	P.M.
OVERHEAD (4G)	1	68,781.0	82,963.0	22	P.M.
	2	62,488.0	84,228.0	18	P.M.
PARENT METAL(S)	465E2402	59,615.0	84,316.0	26	N.A.

TEST DATA — GUIDED BEND TEST								
DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

Figure 5-8. Certification and Test Data — Procedure No. 2

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Metal Arc  
 MATERIAL ASTM A302-56 Grade B WELDED TO Same  
 PLATE THICKNESS 1/2" BACKING STRIP THICKNESS None  
 THICKNESS RANGE THIS TEST QUALIFIES 3/16" through 1"  
 FILLER METAL SPECIFICATIONS ASTM 316-58T; AWS E7018-A1  
 CHEMICAL ANALYSIS C, 0.12; Mn, 0.9; P, 0.03; S, 0.04; Si, 0.80; Mo, 0.40 to 0.65  
 PREHEAT TREATMENT 150° F  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8" FOREHAND OR BACKHAND TECHNIQUE Forehand  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Ductilend 70 Mo  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 70,000  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-4	See Fig. 5-4	See Fig. 5-4
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	8	4	5
INTERPASS TEMPERATURE	300° F (max.)	300° F (max.)	300° F (max.)
AMPERES & VOLTS	100-150A; 22-26V	120-150A; 22-26V	120-140A; 22-26V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	10.3" per hour	12" per hour	14" per hour

**TEST DATA — REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	63,016.0	77,763.0	24	P.M.
	2	62,290.0	76,538.0	22	P.M.
VERTICAL (3G)	1	60,013.0	76,931.0	26	P.M.
	2	60,334.0	76,987.0	23	P.M.
OVERHEAD (4G)	1	58,441.0	75,729.0	24	P.M.
	2	63,581.0	79,052.0	24	P.M.
PARENT METAL(S)	19293	63,785.0	81,108.0	26	N.A.

**TEST DATA — GUIDED BEND TEST**

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

CERTIFIED PROCEDURE								
WELDING PROCESS	Manual Metal Arc							
MATERIAL	ASTM A-302-56 Grade B	WELDED TO	Same					
PLATE THICKNESS	1/2"	BACKING STRIP THICKNESS	1/4"					
THICKNESS RANGE THIS TEST QUALIFIES	3/16" through 1"							
FILLER METAL SPECIFICATIONS	ASMT 31658-58T; AWS E-7018-A1							
CHEMICAL ANALYSIS	C, 0.12; Mn, 0.9; P, 0.03; S, 0.04; Si, 0.80; Mo, 0.40 to 0.65							
PREHEAT TREATMENT	150° F							
FILLER ELECTRODE OR WIRE DIAMETER	1/8"	FOREHAND OR BACKHAND TECHNIQUE	Forehand					
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Ductilend 70 Mo							
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	70,000							
STRESS RELIEVING PROCEDURE	None							
POSTHEAT TREATMENT	None							
	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)					
TYPE JOINT	See Fig. 5-5	See Fig. 5-5	See Fig. 5-5					
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)					
NUMBER OF PASSES	8	5	6					
INTERPASS TEMPERATURE	300° F (max.)	300° F (max.)	300° F (max.)					
AMPERES & VOLTS	120-160A; 22-26V	100-130A; 22-24V	120-140A; 22-24V					
AVERAGE WELDING RATE COMPLETE CROSS SECTION	14.4" per hour	12" per hour	8" per hour					
TEST DATA — REDUCED SECTION TENSILE TEST								
DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE			
HORIZONTAL (2G)	1	62,363.0	79,212.0	24	P.M.			
	2	61,770.0	79,731.0	23	P.M.			
VERTICAL (3G)	1	59,713.0	79,140.0	22	P.M.			
	2	62,345.0	77,344.0	22	P.M.			
OVERHEAD (4G)	1	61,991.0	76,393.0	19	P.M.			
	2	62,817.0	77,558.0	21	P.M.			
PARENT METAL(S)	19293	63,785.0	81,108.0	26	N.A.			
TEST DATA — GUIDED BEND TEST								
DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

Figure 5-10. Certification and Test Data — Procedure No. 4

### CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc  
 MATERIAL ASTM A212-61T Grade B WELDED TO Same  
 PLATE THICKNESS 3/8" BACKING STRIP THICKNESS None  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 3/4"  
 FILLER METAL SPECIFICATIONS ASTM-233-58T; AWS E-7018  
 CHEMICAL ANALYSIS Mo, 0.30\*; Mn, 1.25\*; Cr, 0.20\*; Ni, 0.30\*; V, 0.08\*; Si, 0.90  
 PREHEAT TREATMENT 200° F  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8" and 5/32" FOREHAND OR BACKHAND TECHNIQUE Forehand  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Ductilend 70 E  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 70,000  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT None

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-4	See Fig. 5-4	See Fig. 5-4
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	8	4	4
INTERPASS TEMPERATURE	300 F (max.)	300° F (max.)	300° F (max.)
AMPERES & VOLTS	100-210A; 20-24V	100-152A; 20-26V	100-120A; 20-24V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	8" per hour	4.8" per hour	8" per hour

#### TEST DATA — REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	53,955.0	76,612.0	9	P.M.
	2	53,571.0	77,142.0	14	P.M.
VERTICAL (3G)	1	50,175.0	76,768.0	16	P.M.
	2	53,345.0	75,768.0	12	P.M.
OVERHEAD (4G)	1	55,150.0	76,870.0	13	P.M.
	2	51,633.0	75,463.0	12	P.M.
PARENT METAL(S)	478L1216	51,178.0	77,470.0	34	N.A.

#### TEST DATA — GUIDED BEND TEST

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

\*Total shall not exceed 1.50

Figure 5-11. Certification and Test Data — Procedure No. 5

CERTIFIED PROCEDURE								
WELDING PROCESS	Manual Metal Arc							
MATERIAL	ASTM A212-61T Grade B	WELDED TO	Same					
PLATE THICKNESS	3/8"	BACKING STRIP THICKNESS	1/4"					
THICKNESS RANGE THIS TEST QUALIFIES	1/16 through 3/4"							
FILLER METAL SPECIFICATIONS	ASTM 233-58T; AWS E-7018							
CHEMICAL ANALYSIS	Mo, 0.30*; Cr, 0.20*; Mn, 1.25*; Ni, 0.30*; V, 0.88*; Si, 0.90							
REHEAT TREATMENT	100° F							
FILLER ELECTRODE OR WIRE DIAMETER	1/8" and 5/32"	FOREHAND OR BACKHAND TECHNIQUE	Forehand					
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Ductilend 70 E							
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	70,000							
STRESS RELIEVING PROCEDURE	None							
POSTHEAT TREATMENT	None							
	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)					
TYPE JOINT	See Fig. 5-5	See Fig. 5-5	See Fig. 5-5					
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)					
NUMBER OF PASSES	11	3	5					
INTERPASS TEMPERATURE	300° F (max.)	300° F (max.)	300° F (max.)					
AMPERES & VOLTS	150-220A; 20-24V	110-150A; 22-24V	125-140A; 22V					
AVERAGE WELDING RATE COMPLETE CROSS SECTION	16" per hour	12" per hour	12" per hour					
TEST DATA — REDUCED SECTION TENSILE TEST								
DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE			
HORIZONTAL (2G)	1	60,425.0	77,325.0	16	P.M.			
	2	61,189.0	77,461.0	14	P.M.			
VERTICAL (3G)	1	61,077.0	76,243.0	20	P.M.			
	2	55,952.0	76,616.0	14	P.M.			
OVERHEAD (4G)	1	61,174.0	78,534.0	15	P.M.			
	2	56,065.0	77,459.0	18	P.M.			
PARENT METAL(S)	761061	50,722.0	76,312.0	38	N.A.			
	56334	45,696.0	75,338.0	33	N.A.			
TEST DATA — GUIDED BEND TEST								
DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

\*Total shall not exceed 1.50

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Figure 5-12. Certification and Test Data — Procedure No. 6

### CERTIFIED PROCEDURE

WELDING PROCESS Manual Metal Arc  
 MATERIAL ASTM A353-58 Grade B WELDED TO Same  
 PLATE THICKNESS 5/16" BACKING STRIP THICKNESS None  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 5/8"  
 FILLER METAL SPECIFICATIONS MIL-E-22200/3A Amend #1; MIL-E8N12; ASTM B295-54T  
 CHEMICAL ANALYSIS Cu, 0.50; Mn, 5.0-9.5; Fe, 10.0; Si, 1.00; C, 0.10; S, 0.015; Ni, Remainder  
 PREHEAT TREATMENT 250° F  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8" FOREHAND OR BACKHAND TECHNIQUE Forehand  
 TRADE NAME ROD USED TO OBTAIN DATA Inconel 182T  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000  
 STRESS RELIEVING PROCEDURE 1050° F for 2 hr; Cool at 300° F/hr to 600° F; Furnace Cool Remainder  
 POSTHEAT TREATMENT Heat to Preheat Temperature, Asbestos Wrap for Slow Cooling

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-4	See Fig. 5-4	See Fig. 5-4
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	10	7	5
INTERPASS TEMPERATURE	400° F (max.)	400° F (max.)	400° F (max.)
AMPERES & VOLTS	110-130A; 22-28V	100-130A; 22-26V	100-130A; 22-26V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	10.2" per hour	18.6" per hour	13.4" per hour

#### TEST DATA — REDUCED SECTION TENSILE TEST

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	84,257.0	103,892.0	13	Weld
	2	87,580.0	90,586.0	6	Weld
VERTICAL (3G)	1	80,287.0	97,921.0	7	Weld
	2	75,803.0	84,862.0	5	Weld
OVERHEAD (4G)	1	80,175.0	103,596.0	13	Weld
	2	89,989.0	104,586.0	8	Weld
PARENT METAL(S)	12393	110,273.0	116,751.0	24	N.A.

#### TEST DATA — GUIDED BEND TEST (LONGITUDINAL\*)

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

\*Per ASME Code Case 1308-4

Figure 5-13. Certification and Test Data — Procedure No. 7



**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Metal Arc

MATERIAL ASTM A-353-58 Grade B WELDED TO Same

PLATE THICKNESS 5/16" BACKING STRIP THICKNESS 1/4"

THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 5/8"

FILLER METAL SPECIFICATIONS MIL-E-22200/3A Amend #1; MIL-E8N12; ASTM B295-54T

CHEMICAL ANALYSIS Cu, 0.50; Mn, 5.0-9.5; Fe, 10.0; Si, 1.00; C, 0.10; S, 0.015; Ni, Remainder

PREHEAT TREATMENT 250° F

FILLER ELECTRODE OR WIRE DIAMETER 1/8" FOREHAND OR BACKHAND TECHNIQUE Forehand

TRADE NAME ROD USED TO OBTAIN DATA Inconel 182T

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000

STRESS RELIEVING PROCEDURE 1050° F for 2 hr; Cool at 300° F/hr to 600° F; Furnace Cool Remainder

POSTHEAT TREATMENT Heat to Preheat Temperature, Asbestos Wrap for Slow Cooling.

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-5	See Fig. 5-5	See Fig. 5-5
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	10	7	5
INTERPASS TEMPERATURE	400° F (max.)	400° F (max.)	400° F (max.)
AMPERES & VOLTS	110-130A; 22-26V	100-130A; 22-26V	100-130A; 22-26V
WELDING RATE	13.4" per hour	10.2" per hour	9.6" per hour
COMPLETE CROSS SECTION			

**TEST DATA — REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	70,866.0	102,125.0	14	Weld
	2	78,415.0	104,080.0	14	Weld
VERTICAL (3G)	1	63,191.0	99,631.0	14	Weld
	2	68,692.0	93,683.0	10	Weld
OVERHEAD (4G)	1	68,452.0	98,263.0	13	Weld
	2	66,328.0	98,403.0	13	Weld
PARENT METAL(S)	12393	110,273.0	116,751.0	24	N.A.

**TEST DATA — GUIDED BEND TEST (LONGITUDINAL\*)**

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

\*Per ASME Code Case 1308-4 Figure 5-14. Certification and Test Data -- Procedure No. 8

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Metal Arc  
 MATERIAL ASTM A203-61 Grade E WELDED TO Same  
 PLATE THICKNESS 3/8" BACKING STRIP THICKNESS None  
 THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 3/4"  
 FILLER METAL SPECIFICATIONS ASTM 316-58T; AWS E-8016-C2  
 CHEMICAL ANALYSIS C, 0.12; Mn, 1.20; P, 0.03; S, 0.04; Si, 0.6-0.8; Mo, 3.0 to 3.75  
 PREHEAT TREATMENT 2G, 200° F; 3G & 4G, 150° F  
 FILLER ELECTRODE OR WIRE DIAMETER 1/8" and 5/32" FOREHAND OR BACKHAND TECHNIQUE Forehand  
 TRADE NAME ROD USED TO OBTAIN DATA Arcos Nickend 3  
 NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 80,000  
 STRESS RELIEVING PROCEDURE None  
 POSTHEAT TREATMENT Heated to Preheat Temperature, Asbestos Wrapped for Slow Cooling

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-4	See Fig. 5-4	See Fig. 5-4
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	7	4	9
INTERPASS TEMPERATURE	400° F (max.)	400° F (max.)	400° F (max.)
AMPERES & VOLTS	120-180A; 20-22V	110-140A; 22-24V	100-150A; 20-23V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	14.4" per hour	12" per hour	9.6" per hour

**TEST DATA — REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	64,014.0	79,848.0	10	P.M.
	2	63,740.0	79,453.0	14	P.M.
VERTICAL (3G)	1	61,337.0	77,834.0	23	P.M.
	2	63,143.0	77,902.0	21	P.M.
OVERHEAD (4G)	1	58,774.0	76,130.0	22	P.M.
	2	62,631.0	77,501.0	22	P.M.
PARENT METAL(S)	52174-25	59,203.0	81,379.0	32	N.A.
	A-7822	56,166.0	78,319.0	34	N.A.

**TEST DATA — GUIDED BEND TEST**

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

CERTIFIED PROCEDURE								
WELDING PROCESS <u>Manual Metal Arc</u>								
MATERIAL <u>ASTM A-203-61 Grade E</u>		WELDED TO <u>Same</u>						
PLATE THICKNESS <u>3/8"</u>	BACKING STRIP THICKNESS <u>1/4"</u>							
THICKNESS RANGE THIS TEST QUALIFIES <u>1/16" through 3/4"</u>								
FILLER METAL SPECIFICATIONS <u>ASTM 316-58T; AWS E-8016-C2</u>								
CHEMICAL ANALYSIS <u>C, 0.12; Mn, 1.20; P, 0.03; S, 0.04; Si, 0.6-0.8; Mo, 3.0 to 3.75</u>								
PREHEAT TREATMENT <u>200° F</u>								
FILLER ELECTRODE OR WIRE DIAMETER <u>1/8" and 5/32"</u>		FOREHAND OR BACKHAND TECHNIQUE <u>Forehand</u>						
TRADE NAME ROD USED TO OBTAIN DATA <u>Arcos Nickend 3</u>								
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION <u>80,000</u>								
STRESS RELIEVING PROCEDURE <u>None</u>								
POSTHEAT TREATMENT <u>Heated to Preheat Temperature; Asbestos Wrapped for Slow Cooling</u>								
	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)					
TYPE JOINT	See Fig. 5-5	See Fig. 5-5	See Fig. 5-5					
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)					
NUMBER OF PASSES	9	5	7					
INTERPASS TEMPERATURE	400° F (max.)	400° F (max.)	400° F (max.)					
AMPERES & VOLTS	120-190A; 20-24V	145-160A; 20-22V	120-145A; 20-22V					
AVERAGE WELDING RATE COMPLETE CROSS SECTION	10.3" per hour	16" per hour	11.1" per hour					
TEST DATA — REDUCED SECTION TENSILE TEST								
DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE			
HORIZONTAL (2G)	1	55,929.0	73,086.0	12	P.M.			
	2	57,110.0	72,339.0	22	P.M.			
VERTICAL (3G)	1	58,781.0	73,924.0	22	P.M.			
	2	60,098.0	72,713.0	22	P.M.			
OVERHEAD (4G)	1	56,219.0	72,864.0	24	P.M.			
	2	60,142.0	73,373.0	20	P.M.			
PARENT METAL(S)	2100850	59,386.0	74,116.0	34	N.A.			
TEST DATA — GUIDED BEND TEST								
DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

Figure 5-16. Certification and Test Data — Procedure No. 10

**CERTIFIED PROCEDURE**

WELDING PROCESS Manual Metal Arc

MATERIAL USS T-1, Type A WELDED TO Same

PLATE THICKNESS 3/8" BACKING STRIP THICKNESS None

THICKNESS RANGE THIS TEST QUALIFIES 1/16" through 3/4"

FILLER METAL SPECIFICATIONS ASTM 316-58T; AWS E-12015G

CHEMICAL ANALYSIS Mo, 0.20; Cr, 0.30; Mn, 1.00; Si, 0.80; Ni, 0.50; V, 0.10

PREHEAT TREATMENT 150° F

FILLER ELECTRODE OR WIRE DIAMETER 1/8" FOREHAND OR BACKHAND TECHNIQUE Forehand

TRADE NAME ROD USED TO OBTAIN DATA Arcos Tensilend 120

NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION 120,000

STRESS RELIEVING PROCEDURE None

POSTHEAT TREATMENT None

	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)
TYPE JOINT	See Fig. 5-4	See Fig. 5-4	See Fig. 5-4
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)
NUMBER OF PASSES	8	4	3
INTERPASS TEMPERATURE	400° F (max.)	400° F (max.)	400° F (max.)
AMPERES & VOLTS	120-135A; 20-24V	100-140A; 20-24V	110-140A; 20-22V
AVERAGE WELDING RATE COMPLETE CROSS SECTION	10.3" per hour	9.0" per hour	12" per hour

**TEST DATA — REDUCED SECTION TENSILE TEST**

DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE
HORIZONTAL (2G)	1	104,760.0	108,018.0	7	P.M.
	2	104,970.0	112,084.0	10	P.M.
VERTICAL (3G)	1	92,100.0	109,100.0	10	Weld
	2	91,400.0	106,300.0	10	Weld
OVERHEAD (4G)	1	93,105.0	105,500.0	13	P.M.
	2	92,784.0	105,412.0	18	P.M.
PARENT METAL(S)	633892	118,792.0	123,957.0	20	N.A.

**TEST DATA — GUIDED BEND TEST**

DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

CERTIFIED PROCEDURE								
WELDING PROCESS	Manual Metal Arc							
MATERIAL	USS T-1, Type A	WELDED TO	Same					
PLATE THICKNESS	3/8"	BACKING STRIP THICKNESS	1/4"					
THICKNESS RANGE THIS TEST QUALIFIES	1/16" through 3/4"							
FILLER METAL SPECIFICATIONS	ASTM 316-58T; AWS E-12015G							
CHEMICAL ANALYSIS	Mo, 0.20; Cr, 0.30; Mn, 1.00; Si, 0.80; Ni, 0.50; V, 0.10							
PREHEAT TREATMENT	2G and 3G, 200° F; 4G, 250° F							
FILLER ELECTRODE OR WIRE DIAMETER	1/8" and 5/32"	FOREHAND OR BACKHAND TECHNIQUE	Forehand					
TRADE NAME ROD USED TO OBTAIN DATA	Arcos Tensilend 120							
NORMAL ULTIMATE (P.S.I.) THROUGH WELD SECTION	120,000							
STRESS RELIEVING PROCEDURE	None							
POSTHEAT TREATMENT	None							
	HORIZONTAL (2G)	VERTICAL (3G)	OVERHEAD (4G)					
TYPE JOINT	See Fig. 5-5	See Fig. 5-5	See Fig. 5-5					
POSITION OF PLATE AND GROOVE	Plate Vertical, Axis of Weld Horizontal. (See Fig. 5-1.)	Plate Vertical, Axis of Weld Vertical. (See Fig. 5-2.)	Plate Horizontal and Overhead, Axis of Weld Horizontal. (See Fig. 5-3.)					
NUMBER OF PASSES	8	5	4					
INTERPASS TEMPERATURE	400° F (max.)	400° F (max.)	400° F (max.)					
AMPERES & VOLTS	140-200A; 20-26V	110-140A; 20-24V	125-175A; 20-26V					
AVERAGE WELDING RATE	7.2" per hour	16" per hour	6.9" per hour					
COMPLETE CROSS SECTION								
TEST DATA — REDUCED SECTION TENSILE TEST								
DESCRIPTION	SPECIMEN OR HEAT NUMBER	YIELD POINT P.S.I.	ULTIMATE TENSILE P.S.I.	DUCTILITY %	LOCATION OF FAILURE			
HORIZONTAL (2G)	1	102,028.0	112,971.0	12	P.M.			
	2	97,279.0	109,149.0	8	P.M.			
VERTICAL (3G)	1	95,778.0	117,708.0	14	Weld			
	2	103,836.0	117,708.0	14	Weld			
OVERHEAD (4G)	1	106,444.0	110,285.0	8	P.M.			
	2	94,716.0	109,569.0	8	P.M.			
PARENT METAL(S)	633892	118,792.0	123,957.0	20	N.A.			
TEST DATA — GUIDED BEND TEST								
DESCRIPTION	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT	TYPE AND SPEC. NO.	RESULT
HORIZONTAL (2G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
VERTICAL (3G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK
OVERHEAD (4G)	1 Root	OK	2 Root	OK	1 Face	OK	2 Face	OK

Figure 5-18, Certification and Test Data — Procedure No. 12



## SECTION VI

### HEAT TREATMENT

#### 6-1. GENERAL

6-2. Heat treatments are developed for, and employed on, particular types of materials to obtain the necessary properties of materials for a specified process or service. Specific types of heat treatment will provide a wide range of mechanical properties required for various applications.

6-3. The following heat treatment methods will be discussed in this Section:

- a. Preheating
- b. Postheating
- c. Stress Relieving
- d. Annealing
- e. Normalizing
- f. Solution Heat Treatment (Stainless Steels)
- g. Solution and Aging of Aluminum Alloys

6-4. In general, the selection of heat treatment for a specific purpose is governed by a number of factors, including chemical composition of materials, and properties required in the materials for satisfactory performance in a specified service. Other important factors to consider are the various temperatures involved, and the methods of cooling after exposure to these temperatures.

#### 6-5. STEELS

6-6. Steel is fundamentally an alloy of iron and carbon. The amount of carbon in steel rarely exceeds 1.10%. A steel which contains only carbon and modest amounts of manganese as alloying elements is defined as plain carbon steel.

#### 6-7. LOW CARBON STEELS.

6-8. Low carbon steels (mild steels) include American Iron and Steel Institute (AISI) C1008 to C1030, and contain the following chemical composition:

Carbon - 0.10 to 0.34%

Manganese - 0.25 to 1.50%

Iron - Remainder

6-9. In general, these steels do not contain sufficient carbon to cause appreciable hardening or loss of ductility at any cooling speed. Preheating or postheating

is not usually required except in heavy sections where preheating or postheating tends to reduce complex heating and cooling stresses, and controls distortion.

#### 6-10. MEDIUM CARBON STEELS.

6-11. Medium carbon steels include AISI C1035 to C1055, and contain:

Carbon - 0.30 to 0.60%

Manganese - 0.60 to 1.65%

Iron - Remainder

6-12. Because of their carbon content, these steels readily harden when heated to welding temperatures and allowed to cool at speeds greater than those known as the "critical cooling rate".

6-13. Medium and high carbon steels (containing over 0.35% carbon), are welded successfully, provided precautions are taken, and the cooling rate is sufficiently retarded to prevent excessive hardening. These steels are readily hardened, with a resulting hardness that may range from soft, in the annealed condition, to greater than 65 Rockwell C. Using a drastic quench treatment, the depth of hardening will vary greatly with the carbon content and especially with the amount of alloying elements present. Therefore, sudden or rapid cooling from the welding temperature may result in a very hard, and sometimes brittle zone adjacent to the weld joint. Any considerable mixture of the high carbon base material into the weld melt may also result in a hard, brittle weld metal deposit.

6-14. The rate of cooling can be retarded by preheating the base materials to a suitable temperature in such a manner that weld deposits are not quickly chilled by rapid heat absorption by the cold base material. This is especially important on heavy sections of thick materials which have a greater capacity to absorb heat. Instances in which welding is performed on heavier materials, a preheat of sufficient temperature must be used to prevent haadening of the weld deposits or adjoining base metals.

6-15 Increases in the carbon content may produce a tendency toward underbead cracking in the base metal adjacent to the weld metal deposit in the fusion zone. This underbead cracking is especially a potential defect with heavy steel plate materials, and is further aggravated by low temperature conditions during welding. Preheating, when properly applied, will usually remedy this condition.

6-16. Preheating to a temperature range of 400 to 500° F will usually produce a ductile joint. Postheating to

1100 to 1200° F is helpful in modifying brittle micro-structure caused by cooling the material too rapidly.

#### 6-17. HIGH CARBON STEELS.

6-18. High carbon steels include AISI C1060 to C1095, and contain:

Carbon - 0.55 to 1.03%

Manganese - 0.30 to 1.00%

Iron - Remainder

6-19. These steels are subject to grain growth and hardening as a result of welding; however, preheating in the range of 500 to 600° F is helpful in preventing these conditions. Postheating at 1100 to 1200° F will improve the ductility and relieve stresses of this material.

#### 6-20. ALLOY STEELS.

6-21. Steels containing either a high magnesium content (in excess of 1.00 percent) or significant amounts of any other alloying elements such as nickel, chromium, molybdenum, etc., are known as alloy steels.

#### 6-22. GENERAL DEFINITIONS

6-23. FERRITE. Ferrite is practically pure iron, and is the principal constituent of low carbon steels, either the plain carbon or low-alloy types. When heated to a temperature in excess of the lower critical temperature, ferrite becomes nonmagnetic and is known as austenite.

6-24. AUSTENITE. Austenite is the nonmagnetic form of iron, and has the capability to dissolve carbon and other alloying elements. This makes it possible to harden most steels by heating the materials to a temperature in excess of the lower critical temperature (which dissolves the alloys present) and then rapidly cooling the steel to produce hardening.

6-25. CEMENTITE. Cementite, or iron carbide, is a chemical compound of iron and carbon ( $Fe_3C$ ). It is a very hard, crystalline material and is the constituent which imparts hardness to steel. This material is magnetizable, but not as readily so as is ferrite.

6-26. PEARLITE. Pearlite is a mechanical mixture of ferrite and cementite.

6-27. MARTENSITE. Martensite is an extremely hard constituent of steel, formed by the rapid transformation of austenite during cooling.

6-28. EUTECTOID STEEL. Eutectoid steel contains approximately 0.85% carbon, has an eutectoid temperature of approximately 1330° F, at which point the austenite instantaneously changes to pearlite and ferrite. The upper and lower critical temperatures and the eutectoid temperature (1330° F) are identical for this material.

6-29. KILLED STEEL. Killed steel represents the optimum extreme of deoxidation. The steel is fully deoxidized by addition of aluminum or silicon (or both) to combine with the oxygen present in molten steel. From the viewpoint of minimal chemical segregation and uniform mechanical properties, killed steel is used when a homogeneous structure and internal soundness is required. This steel can be produced with either fine or coarse grained structures without affecting the soundness, surface condition, or cleanliness of the metal.

6-30. CRITICAL TEMPERATURE RANGE. In this range steels undergo internal atomic changes which radically affect the properties of the material.

6-31. LOWER CRITICAL TEMPERATURE. When a plain carbon or low steel is heated to its lower critical temperature, (approximately 1350° F) the solid ferrite and solid pearlite begin to dissolve and merge to form austenite, which is non-magnetic. This dissolving action continues on heating through the upper critical range (1650° F) until the solid solution becomes complete.

6-32. UPPER CRITICAL TEMPERATURE. The upper critical temperature (approximately 1650° F for plain carbon and low alloy steels) is the upper limit of temperature of the transformation range. The upper critical temperature lowers as the carbon content increases to approximately 0.85% (the eutectoid point).

6-33. PREHEATING. Refer to Paragraphs 3-106 through 3-113.

6-34. POSTHEATING. Refer to Paragraphs 3-119 through 3-122.

6-35. ANNEALING. Annealing is a softening process in which metal is heated to a specified temperature and held a sufficient time at this temperature, then cooled at a controlled rate to produce small grain size, softness, good ductility, and other desired properties.

6-36. NORMALIZING. Normalizing is a process in which a ferrous alloy (iron or steel) is heated to a temperature greater than the transformation range, and is subsequently cooled in still air to room temperature. On cooling, the austenite transforms, giving somewhat higher strength and hardness, and slightly less ductility than that resulting from annealing.

6-37. STRESS-RELIEVING. Stress-relief heat treatment consists of uniformly heating the materials to specific temperature (usually lower than the full annealing temperature) and holding or soaking at this temperature one hour or more per inch of material thickness, and then cooling to ambient temperature at a controlled rate. The purpose of this treatment is to relieve the materials of locked-up or residual stresses.

6-38. BURNING RANGES. The burning range for steel is 2500 to 2750° F. Adequate measures should be taken



to protect steels from this temperature range. Burned steel cannot be cured or recovered except by remelting.

6-39. **BLUE BRITTLE RANGE.** The blue brittle range temperature for most carbon and most low-alloy steels occurs at 400 to 700° F. There shall be no peening or working of steels when the material is in the blue brittle condition.

#### 6-40. EFFECTS OF ALLOY ELEMENTS IN STEEL.

##### 6-41. ALUMINUM.

6-42. Aluminum is extensively used as a deoxidizer in steel production. As such, it is an effective purifier. Aluminum also reduces grain growth by forming dispersed oxides and nitrides, which act as nuclei for the formation of more (and thus smaller) grains.

##### 6-43. CARBON.

6-44. Carbon is the principal hardening agent in steel. Alloy steels containing more than 0.20% carbon are considered heat-treating steels, and are heat-treated to obtain increased strength and hardness. As the principal hardening element in most alloy steels, carbon has about the same effect as it does in plain carbon steels.

##### 6-45. CHROMIUM.

6-46. As a constituent in alloy steel, chromium has a strong hardening effect on the steel as it cools from welding temperatures. Those steels containing a higher percentage of chromium (12 to 30%) exhibit an increased corrosion resistance at both high and low temperatures. Consequently, chromium is one of the basic ingredients used in production of stainless steels. It is also one of the basic ingredients in steels that are to be used for high temperature service where resistance to oxidation is a requirement. There is very little loss of strength in chrome steels at temperatures as great as 900° F.

##### 6-47. COBALT.

6-48. Cobalt is used as an alloying agent in steels for which high strength or high hardness at elevated temperatures are desired. It imparts the quality known as red-hardness.

##### 6-49. MANGANESE.

6-50. Manganese is the most indispensable alloying ingredient used in steel making. When manganese appears in steels in amounts as much as approximately 0.80% it is generally intended for the purpose of combining with sulphur or phosphorus to eliminate embrittlement and "hot shortness". In higher percentages, (1.0 to 15% with one exception) manganese increases the toughness of the metal, and also increases the hardenability of the metal involved. The exception is a content of between 3.0 and 4.0% of manganese in steel, which tends to promote embrittlement.

##### 6-51. MOLYBDENUM.

6-52. Molybdenum tends to increase the hardness and endurance limits of steel. It also contributes to deep hardening, and decreases the tendency toward temperature creep or slow stretching of steel under stress at elevated temperatures. Molybdenum also increases the corrosion resistant qualities in stainless types of alloy steel, and prevents temper embrittlement (similar to blue brittle) of low chrome alloy. Generally, it is used in comparatively small quantities, ranging from 0.10% to 0.40%.

##### 6-53. NICKEL.

6-54. Nickel is used as an alloying agent in steel for the purpose of increasing strength and toughness at low temperatures. General quantities used are from 1.0% to 4.0%. In some special alloys, the nickel content may be as much as 36% or more. In all cases, the addition of nickel will increase the strength without decreasing the toughness of the steel.

6-55. Steels having a nickel content of 24% are practically nonmagnetic, and when the quantity is increased to 36%, the coefficient of expansion due to heat (up to 900° F) is very small. In the lower range of nickel, i.e., as much as approximately 4.0%, it is estimated that the tensile strength is increased approximately 6,000 psi for each additional percent of nickel.

##### 6-56. PHOSPHORUS.

6-57. Phosphorus is an element usually found in all steels. When present in high percentages, it is considered an impurity. In low percentages however, it improves the machinability of high carbon as well as low carbon steels. For this purpose, the phosphorus content is usually restricted to approximately 0.05%, particularly so in steels in the higher carbon ranges. Phosphorus slightly improves the strength and corrosion resistance of low-carbon steels.

##### 6-58. SILICON.

6-59. Silicon acts to promote fluidity of the molten steel bath by effecting a control over the oxygen content of steel. It is used extensively in high percentages to produce certain magnetic characteristics in steel used for electrical and magnetic applications. Silicon also tends to improve oxidation resistance, and increases the hardenability of steels carrying non-graphitizing elements. It also contributes to the strength of low alloy steels.

##### 6-60. TUNGSTEN.

6-61. Tungsten is used as an alloying element in tool steel, and tends to produce a fine, dense grain when used in relatively small quantities. When used in larger quantities (ranging from 17 to 20%) and in combination with other alloys, it produces a steel that retains its hardness at elevated temperatures. Tungsten is also used in certain heat-resistant steels where re-

tention of strength at elevated temperatures is important. This element is usually used in combination with chromium or other alloying agents.

6-62. VANADIUM.

6-63. Vanadium is used in production of steel as a constituent to control grain size. It tends to promote hardenability and causes marked secondary hardness, yet resists tempering. The addition of vanadium helps to produce a fine grain structure during the heat treating process. Because of this, vanadium often eliminates the bad effects of overheating.

6-64. COPPER.

6-65. The effect of copper as an alloying element in iron or steel is generally mild. It may be utilized to some extent as a precipitation hardening element in iron or steel by resorting to a solution heat treatment, followed by an aging treatment. Copper in solid solution slightly increases the hardenability of steel by making the austenite transformation more sluggish. Low-alloy steels may contain copper additions as much as 4.0% to provide added strength and corrosion resistance.

6-66. SULPHUR AND SELENIUM.

6-67. Sulphur and selenium are discussed collectively because both of these elements react identically, and can be used interchangeably. Sulphur has a melting point of 246° F, and selenium melts at 428° F. Both elements show appreciable solubility in iron, but due to their low boiling points, cannot be retained in molten iron in large quantities. For most steels, a maximum content of 0.04% is adhered to for either sulphur or selenium. Steels for special applications, or critical weldability requirements, may demand that sulphur or selenium contents be no more than 0.01% maximum.

6-68. Sulphur is the principal base metal element affecting weld metal porosity, and also contributes to high temperature cracking in the weld zones. When sulphur is present as iron sulphide (FeS), it forms at a temperature of 1805° F as a low melting eutectic which collects in the grain boundaries and reduces cohesion between the grains. In quantities greater than 0.05%, and in the presence of hydrogen from the welding arc atmosphere, this element forms hydrogen sulphide (H<sub>2</sub>S) bubbles which are generally entrapped in the weld metal. This condition is more severe when welding with electrodes having cellulose type coverings.

6-69. COLUMBIUM AND TITANIUM.

6-70. Columbium and titanium both have a strong affinity for carbon. Columbium has a melting point of 4380° F, and titanium melts at 3272° F. Both elements unite with carbon, oxygen, and nitrogen in steel; titanium having the greater uniting tendency in all cases. As the concentration of these two elements increases in steel, the tendency to harden decreases. Titanium is used as an alloy addition to reduce hardenability of

steel to be welded by forming carbides which require more elevated temperatures (or longer time periods) to dissolve in the austenite. The greatest use of columbium and titanium is in alloying stainless steels of the austenitic type, where these elements act as carbide stabilizers.

6-71. CARBON AND LOW ALLOY STEELS.

6-72. PREHEATING.

6-73. Preheating may or may not be required for a specific material or welding procedure. However, it is absolutely essential that an adequate preheating procedure be used (when necessary) to ensure that mechanical properties of weldments, such as yield strength, tensile strength, ductility, and corrosion resistance will be satisfactory for the intended service.

6-74. Whatever effect preheating may have on materials, it is an accepted rule that it lowers the cooling rate after welding; the higher the preheating temperature, the slower the cooling rate after welding is completed. The slower cooling rates are caused by the reduction in temperature gradients and by the lower thermal conductivity of the material at the preheat temperatures.

6-75. Reduction of the cooling rate by preheating increases the time interval in the heat-affected zones in the temperature range of 1000 to 1200° F, and promotes the transformation of austenite to pearlite instead of martensite. Therefore, preheating of weld areas before and during welding, will reduce hardening of metals.

6-76. Hardened zones often occur in the heat-affected areas adjacent to welds in medium and high-carbon steels. The hard zones may produce cracks in the base materials during the final stages of cooling from the welding temperature. Preheating to a temperature of 200 to 300° F is recommended for lower carbon and low-alloy steels. This preheat will reduce the cooling rate and prevent formation of hard or brittle zones in the base materials adjacent to the weld joint; thereby substantially lessening the tendency toward cracking.

6-77. Underbead cracking which occurs in certain high-carbon and low-alloy steels when welded in the temperature range of 0 to 70° F (using cellulose covered electrodes and low heat input) may be eliminated by preheating the steels to a temperature of 200 to 300° F before welding.

6-78. Cooling rates at temperatures below 400° F have a definite effect on low-temperature cracking. Acceleration of low-temperature cooling increases the extent of cracking. Some steels, occasionally even mild steels having a carbon content of 0.30% or less, cause less difficulty during welding when they are heated to a temperature of at least 70° F before welding.

6-79. Preheating to temperatures of approximately 600° F is often required to prevent hard zone cracking in steels having more than 0.30% carbon content.

6-80. In cases where preheating procedures are required for medium to high carbon, or low-alloy steels, but are impractical or impossible due to physical characteristics of the structure or weldment, use of low-hydrogen type welding electrodes will minimize the tendency toward cracking or failure of the weld zones. These electrodes are specially designed for this purpose.

6-81. When arc welding electrodes having cellulose-type coverings (E6010) are used to weld carbon and low-alloy steels, hydrogen will be absorbed by the weld metal and the heat-affected zone adjacent to the weld. These cellulose-type coatings generate hot gases during the deposition of the weld metal. One of the final gaseous products of the cellulose is water-vapor and hydrogen. Hydrogen in the weld and base metals can cause porosity, embrittlement, cracking, and subsequent failure of the weldment.

6-82. Use of low-hydrogen type electrodes without metal preheat produce welded joints which are equal to thermally stress-relieved joints made with cellulose covered electrodes. However, with a metal preheat of 200 or 300° F, weldments made with low hydrogen electrodes are superior to the stress-relieved weldments made with cellulose covered electrodes.

#### 6-83. POSTHEAT TREATMENT.

6-84. Postheating is recognized as a means of improving the properties of a weldment. The postheat treatment of a weld joint or welded part may consist of stress-relief, annealing, or normalizing. In general, the differences in heat treating operations are in the temperatures employed and/or the method of cooling. Temperatures for stress-relief heat treatment are generally less than the critical heat range of carbon steels; whereas, temperatures for annealing and normalizing are generally greater than the critical range. While the effects of different heat treatments overlap, each has been developed to serve a specific purpose. The selection of a proper heat treatment requires the consideration of a number of factors including the chemical composition of steel to be treated; stress conditions arising from welding; the microstructure in heat-affected zones; and properties required in the materials for satisfactory performance in service. A review of the above heat-treatments indicates that two different treatments may be used to accomplish the same purpose.

6-85. In joining two pieces of steel by welding, the weld metal deposits and the heated base metal in the weld zone undergo considerable contraction when cooling from an elevated temperature to room temperature. The base metal in the vicinity of a weld is subjected to a thermal cycle in which temperatures from the melting point down to room temperature are involved. Volume changes that accompany the welding operations may cause distortion, residual stresses, or cracking in the weldment.

6-86. The detrimental effect of high residual stresses on the mechanical properties of a weldment containing residual tensile stresses may cause failure at much lower loads than with those structures that are stress-free.

6-87. Postheat treatment in the temperature range of 1100 to 1250° F generally improves the ductility and low-temperature notch toughness of weldments. For some steels, the ductility-transition temperature is restored to the value of the unwelded steel.

6-88. When alloy-steel weld metal is postheated, a knowledge of the mechanical properties in the heat-treated condition is extremely important, due to the fact that some alloy weld metals are severely embrittled at a temperature of approximately 1100°F. At 800 to 1100°F there is also loss of corrosion resistance in non-stabilized austenitic stainless steels.

6-89. In all cases where postheat treatment is required, or indicated for a specific material or welding operation, the Design Engineer shall be consulted and approved procedures obtained prior to the start of any heat treatment.

#### 6-90. STRESS-RELIEVING.

6-91. Stress-relief heat treatment is the uniform heating of a structure, vessel, and/or weldment to a suitable temperature below the critical heat range of the base metal, followed by uniform cooling to relieve residual and/or shrinkage stresses induced by previous fabrication and welding operations.

6-92. Stress-relief heat treatment is expected only to relieve stresses, and not necessarily to produce any changes in the microstructure of the steel. The general effects of a stress-relief treatment are: recovery, relaxation, removal of hard zones, and recrystallization. The first effect is universal; the second effect is achieved when stress-relief heat treatment is conducted at a sufficiently elevated temperature for a specified length of time; the third effect is exerted only if hard zones have formed as a result of fabrication and/or welding.

6-93. Structures and/or weldments may have shrinkage stresses near the yield strength of the materials whether or not there is external restraint during welding. It is desirable to relieve these residual shrinkage stresses to low values as approximate to zero as possible. Unless the stresses are reduced to approximately zero, the parts are subject to brittle failure due to tensile shrinkage stresses and tensile service stresses acting in two or three directions at right angles.

6-94. The first effect that is found during a stress-relieving treatment is recovery. The temperature is elevated uniformly to keep all parts of the structure or weldment at approximately the same temperature, and thus prevent thermal stresses. As the temperature is elevated through the first 400° F, there is no appreciable change in grain structure, yet the shrinkage

stresses decrease. However, the relief of shrinkage stresses at this temperature is inadequate; therefore, the temperature must be raised to higher values. Upon raising the temperature to adequate values, relaxation occurs and shrinkage stresses are relieved to approximately zero.

6-95. The over-all effects of the various heat treatments may overlap due to the more elevated temperatures required for the annealing and/or normalizing heat treatments. In some cases, two different heat treatments can be employed to accomplish the same results, i.e., stress-relieving will be accomplished during either annealing or normalizing treatments.

6-96. The temperature rates of heating and cooling to be used for stress-relieving of structures, vessels, pipe and fittings, or other parts constructed of metals which require stress-relieving shall be as follows:

- a. The furnace temperature shall not exceed 600° F at the time the material is placed in the furnace or heating chamber.
- b. At temperatures greater than 600° F, the rate of heating shall not exceed 400° F per hour divided by the maximum metal thickness. In no case shall the rate of heating exceed 400° F per hour.
- c. During heating from 600° F to the maximum stress-relieving temperature of 1250° F, there shall not be a greater variation than 250° F throughout the part being heated in any 15-foot interval of total length, and when maintained at the holding or soaking temperature, no greater variation than 150° F through the metal thickness or throughout the parts being heated.
- d. A minimum temperature of 1100° F shall be maintained for a period of one hour per inch of maximum metal thickness. During the heating and holding time periods, the furnace atmosphere shall be controlled such as to avoid oxidation of the metal surfaces. The furnace or heating chamber shall be of such design, and controlled in such manner, as to prevent direct impingement of the flame on the metal surface.
- e. At temperatures greater than 600° F, cooling shall be accomplished in a closed furnace or cooling chamber at a rate of 500° F per hour divided by the maximum metal thickness in inches of the part being cooled. In no case shall the temperature rate exceed 500° F per hour. From 600° F to ambient temperature, the metals shall be cooled in still air. All materials shall be allowed to cool by natural means; use of any cooling media to accelerate cooling is not permitted.

6-97. When it is impractical or impossible to stress-relieve at a temperature of 1100° F in accordance with the above-stated procedures, it is permissible to perform the stress-relieving operation at reduced temperatures for extended periods of time in accordance with the following:

METAL TEMPERATURE (DEGREES F)	HOLDING OR SOAKING TIME (HOURS PER INCH OF THICKNESS)
1050 . . . . .	2 Hours
1000 . . . . .	3 Hours
950 . . . . .	5 Hours
900 . . . . .	10 Hours

6-98. For intermediate temperatures, the holding or soaking times must be determined by straight-line interpolation. Cooling from these temperatures shall be in accordance with Paragraph 6-96.

6-99. Vessels, piping systems, or parts fabricated of materials conforming to specification American Society for Testing Materials (ASTM) A 353-58, (9% nickel steel), shall be stress-relieved (when required) by gradually and uniformly heating the steel to a temperature in the range of 1025 to 1085° F, and holding or soaking at that temperature range for a minimum of two hours for thicknesses up to one inch, plus a minimum of one hour for each additional one inch of thickness, or fraction thereof. The heating and cooling rates for these materials shall be as specified in Paragraph 9-96.

6-100. The time at temperature in stress-relieving carbon steels is customarily one hour per inch of thickness. However, more time is required at 1100° F than at 1250° F for the same degree of stress-relief.

6-101. Both stress-relieving and preheating are often required for some parts. With complicated parts, or with steels having a pronounced tendency toward cracking, it is often essential that the welded part be placed immediately in the stress-relieving furnace without permitting the part to cool below the preheat temperature.

6-102. Heating of the entire welded fabrication in an enclosed furnace is recommended, and should be used whenever practicable. Heating the completed fabrication in more than one heat in a furnace is permissible, provided the overlap of the heated sections is a minimum of five feet. When this procedure is used, the portion outside of the furnace shall be insulated and protected sufficiently to prevent harmful temperature gradients.

6-103. In cases where stress-relieving is required for a completed structure, vessel, or fabrication, and it is not practicable or possible to heat as a whole (or in two or more heats in the furnace) due to design dimensions, configurations, or other conditions, it is permissible to stress-relieve the various sections and/or parts before joining, provided that the circumferential joints made during final joining of the sections or parts are stress-relieved to complete the fabrication. This

may be accomplished by heating such joints by any appropriate means that will ensure uniformity.

6-104. The width of the heated band on each side of the greatest width of finished welds shall not be less than two times the maximum metal thickness. The portion outside of the heating device shall be protected to prevent harmful temperature gradients. This procedure may also be used to stress-relieve materials after repairs.

6-105. Local stress-relieving of joints in piping or tubing, shall be performed by heating the circumferential joints by any appropriate means over a band having a width on each side of the center line of not less than three times the greatest width of the finished weld. The portion outside of the heated band shall be protected to prevent harmful temperature gradients. The temperatures provided in Paragraph 6-96 shall be the minimum temperature through the thickness of the materials.

6-106. When more than one part is stress-relieved in the same furnace under one heat (or furnace charge), thermocouples shall be placed on the bottom, center, and top of the charge (or in other zones of potential temperature variation) in such manner that indicated temperatures shall be the true temperatures for all parts in those zones.

6-107. Parts of different thickness may be stress-relieved in the same furnace charge provided that the minimum temperature, and the total holding or soaking time, is sufficient to stress-relieve the thickest material in the charge.

#### 6-108. ANNEALING.

6-109. Steel is annealed by various procedures to reduce hardness; improve machinability; facilitate cold-working; produce a desired microstructure; remove stresses; or obtain required mechanical and physical properties.

6-110. Full annealing consists of heating the structure or weldment to approximately 1450 to 1650° F for plain carbon and low-alloy steels. This temperature is maintained one hour per inch of material thickness or fraction thereof, as determined by the thicker material being annealed. The parts are cooled in the furnace, or by some method yielding a slow cooling rate.

6-111. Full annealing of structures and/or weldments is not usually recommended due to the elevated temperatures involved, and the resultant metal distortion that occurs. Some weldments may be annealed under certain conditions provided adequate precautions are taken.

#### 6-112. NORMALIZING.



Care shall be exercised when normalizing high-hardenability steels (such as AISI 4340) to avoid excessive hardening of the material.



The elevated temperature required for annealing and/or normalizing may cause excessive distortion of the completed structure or weldment. When annealing and/or normalizing is required, and the structure or weldment is not self-supporting in the furnace under the maximum temperature to be used, special precautions shall be taken to properly support and protect the parts from distortion or dimensional changes. Special preparations are not required for those instances in which the shape and thickness, or mass of a structure, weldment, or part is self-supporting in the furnace.

6-113. Normalizing is defined as a process wherein ferrous alloys are heated gradually to a suitable temperature (approximately 1650° F) and then allowed to cool in still air to a temperature substantially less than the transformation range.

6-114. Normalizing heat treatment is similar to an annealing heat treatment, and is frequently used in treating steel structures and weldments to improve the properties of both the base metal (prior to welding) and the finished weldment.

6-115. A normalizing heat treatment may be employed to accomplish the following:

- a. Reduce stresses from cold-working or welding.
- b. Remove hardened zones in the heat-affected metals adjacent to welds.
- c. Refine any coarse structure which may remain in the materials through hot-working or forming operations performed at high temperatures (in excess of 1900° F).
- d. Create a more uniform and desirable microstructure in both the base metal and weld metal.
- e. Obtain required mechanical and physical properties.

6-116. Normalizing involves heating the steel to approximately 100° F in excess of the upper critical range of the steel, followed by cooling in still air to room temperature. This treatment may soften, harden, or stress-relieve the steel, depending on the grade and condition of the steel before normalizing.

6-117. Normalizing practice requires that the steel be heated uniformly to a temperature range sufficiently high to ensure complete transformation of ferrite to austenite. It shall remain at this temperature sufficiently long to attain a uniform and even temperature throughout the maximum thickness of the steel.

6-118. Cooling shall be performed in still air, and shall also be uniform around the whole part, or parts, in such manner that in no area is cooling restricted or accelerated. Restriction of the cooling rate will alter the operation from normalizing to an annealing treatment. Accelerating the cooling rate more than that normally achieved by natural circulation of air will result in hardening of the steel.

## 119. STAINLESS STEELS.

### 6-120. AUSTENITIC STAINLESS STEELS.

6-121. Chrome-nickel stainless steels containing more than 17% chrome and more than 7% nickel are termed austenitic (non-hardenable by heat-treating). These steels are identified as the AISI 300-Series (304, 304L or ELC, 316, 347, etc.).

### 6-122. CARBIDE PRECIPITATION.

6-123. These alloys are commonly referred to as "18-8" stainless and are not hardened by welding, but if the material has been hardened by mechanical working, welding may cause softening of the material.

6-124. When these stainless steels are exposed to temperatures of 800 to 1500° F during welding, fabrication, or use, the carbon tends to migrate to the grain boundaries and forms a network of chromium carbide which depletes or robs the areas adjacent to the grain boundaries of chromium, thus making the area susceptible to corrosion. This process is known as intergranular carbide precipitation and results in intergranular corrosion if used in a corrosive environment. The material is "sensitized" if carbide precipitation has occurred.

6-125. The severity of carbide precipitation depends on carbon content, temperature, and time. The higher the carbon content, the higher the temperature in the range of 800 to 1500° F, and the longer the time of exposure, the greater the amount of carbide precipitation. Because of these factors, Type 304L (Extra Low Carbon) is often used to reduce the tendency toward sensitization. In Type 302, carbon content is 0.15% maximum; in Type 304L, carbon is reduced to 0.03% maximum. Sensitization can still occur in this material if exposed for long periods of time (approximately 2 hours) in the carbide precipitation temperature range. Use of low-carbon materials inhibit precipitation a sufficient length of time so that normal welding and stress-relieving operations may be performed without harmful effects. Stainless steels containing less than 0.03% carbon, such as 304L, are more resistant to carbide precipitation than those with higher amounts of carbon. These lower carbon stainless steels can be subjected to temperatures in the range of 800 to 1500° F for as much as two hours without adversely affecting their corrosion resistance. This will allow normal welding and stress-relieving operations to be performed, but these materials should not be subjected to service temperatures greater than 750° F.

6-126. Another method of combating intergranular corrosion in austenitic stainless steels is to add columbium, tantalum, or titanium to the steels, thus producing a stabilized steel. Examples of stabilized austenitic stainless include Types 347 (columbium stabilized) and 321 (titanium stabilized). In general, Type 347 is preferred for applications involving welding, in that titanium burns off as an oxide and is lost or substantially reduced. For this reason, Type 321 is not welded with Type 321 rod, but generally is welded with Type 347 filler rod.

6-127. Carbide precipitation does not appreciably affect the mechanical properties of the material; although the corrosion resistance of the material may be greatly reduced by carbide precipitation, tensile strength and ductility are not altered to any practicable degree.

6-128. When heavier gages of these materials are being welded and service requirements demand the absence of carbide precipitation, precautions must be taken which will cause the weldment to cool more rapidly. This may be accomplished by one of the following methods:

- a. Using small diameter electrodes
- b. Reducing current
- c. Using stringer beads instead of weaving or lacing
- d. Using chill bars of similar materials
- e. Following the welding operation by immediate oil-free air blast, water sprays, or quench.

6-129. Although rapid cooling is desirable to preclude carbide precipitation, care must be taken that cooling rate is not so great that the weldment is unduly stressed or distorted; subsequent stress relieving treatments will aggravate the carbide precipitation. The stress-relieving which will be required due to this stress will place the material in the carbide precipitation range.

6-130. In severely corrosive environments, where it is required that the structures be stress-relieved, the extra low carbon grades shall be used. If these weldments are to be stress-relieved for periods longer than 2 hours, or are used in service requiring temperatures greater than 800° F, stabilized grades such as Types 347 or 321 shall be used.

### 6-131. PREHEAT TREATMENTS.

6-132. The austenitic stainless steels should generally not be preheated. Such treatments prior to welding decrease the rate of cooling, thereby increasing the length of time the material is in the sensitizing range.

6-133. An exception to this practice is made when heavy sections of stabilized grades are used, and are welded under restraint where cracking may be prevented by preheat treatments at temperatures as great as 1000° F.

#### 6-134. SOLUTION ANNEALING.

6-135. If the austenitic stainless steels are sensitized, the carbon and chromium can be redissolved by heating the steels in a range of 1850 to 2050° F for 1/2 to one hour per inch of thickness, but not less than 1/2-hour. Cooling must be rapid to prevent re-precipitation of carbides. This requires water quenching on heavy material sections and water spraying or oil-free air blast on thin sections.

#### 6-136. STRESS-RELIEVING.

6-137. Stress-relieving of austenitic stainless steels is less effective than that for carbon steels at the same temperature, because stainless steels have a high yield strength at elevated temperatures. Thus, stress-relieving in the temperature range from 1100 to 1250° F is less than 50% effective in reducing stresses in austenitic stainless steels.

6-138. Stress-relieving at 1600° F is approximately 90% effective. Generally, on these materials, the detrimental effects of stress-relieving (such as distortion and misalignment) out-weigh the advantages. However, heavy (greater than 3/4-inch) sections should be stress-relieved, as should vessels or piping subjected to potential stress corrosion environments.

6-139. Except for stabilized and low carbon grades, the stress-relieving temperatures shall be maintained at less than 800° F; although at this temperature stress-relief will not be complete, it may be sufficient for reducing stress corrosion and peak residual stresses.

6-140. If higher stress-relieving temperatures are indicated, stabilized or low carbon grades should be used; temperatures of 1350° F for one hour per inch of thickness is customary for these materials.

6-141. If complete stress-relief is required, stabilized grades should be used and temperatures in the range of 1600 to 1800° F employed. However, these temperatures will reduce the strength of cold-worked material, and may cause excessive distortion.

#### 6-142. STRAIGHT CHROMIUM STEEL TYPES (400-SERIES)

6-143. All 400-series stainless steels are magnetic, and are classified in the following groups:

- a. Those containing as much as 14% chromium which harden intensely, and have a cracking tendency if they are allowed to cool rapidly in air from elevated temperatures. The types in this group are referred to as martensitic stainless steels (Types 410, 414, 416, 420, 431, and 440-C).

- b. Those containing from 18 to 30% chromium do not respond to heat treatment, in that they do not harden when air-cooled rapidly from an elevated temperature. These steels are referred to as ferritic (Types 405, 430 and 446).

#### 6-144. MARTENSITIC GRADES.

6-145. Cracking may be minimized by preheating these steels within a range of 600 to 800° F and maintaining these temperatures during welding. Also, a postheat treatment in the range of 1300 to 1450° F shall be applied immediately after welding without intermediate cooling of the weldment. To allow the part to air-cool to room temperatures after welding, and before post-heating, may cause cracking at the weld since the ductility is lowered and the metal is unable to stretch or yield.

#### 6-146. FERRITIC GRADES.

6-147. The higher chromium grades of stainless steel (especially those containing over 20% chromium) are characterized by brittleness, which is the result of grain growth occurring when these types are subjected to the welding heat. This brittleness should not be confused with hardness.

6-148. These alloys may also become embrittled if they are allowed to cool slowly from approximately 1200° F, or are held at this temperature for any appreciable time. Brittleness from this cause can be reduced by cooling thin sections rapidly; a water quench is necessary for thick sections.

6-149. Because grain growth in these alloys cannot be remedied by heat treatment, it is not possible to eliminate brittleness due to slow cooling. Ductility may be improved somewhat by cold-working the weld area by peening, followed by annealing. Peening should be performed at a temperature of approximately 1000° F to avoid cracking the brittle material. After peening, the weld should be reheated to 1450° F and quenched rapidly to room temperature.

6-150. When it is impossible to heat-treat the martensitic or ferritic grades, they may be welded with austenitic 25 chrome—20 nickel rod, if the specification allows this procedure. In such cases, the practice is to preheat to a range of 400 to 600° F, and maintain this temperature until welding has been completed.

6-151. The straight chromium stainless steels should not always be welded with austenitic rods. Those instances in which welds in high temperature service will be subjected to frequent shutdown or cyclic changes in temperature, straight chromium stainless materials should be welded using straight chromium rods of similar composition. This will avoid the thermal stresses which otherwise develop from using a weld metal with a significant difference in the coefficient of thermal expansion from that of the base

metal. Austenitic weld deposit will expand almost twice as much per inch as ferritic-martensitic material per temperature degree rise in the temperature range of 100 to 1000° F.

**6-152. ALUMINUM.**

6-153. Aluminum is categorized in the following groups:

- a. Those which are hardened by heat treating (or heat-treatable types). Type 6061 is an example of a heat-treatable aluminum alloy.
- b. Those which are not hardenable by heat treating; these nonheat-treatable types can only be hardened by working the material. Type 3003 is an example of nonheat-treatable aluminum alloy.

6-154. The heat-treatable grades generally gain hardness as a result of precipitating material out of a solid solution. When completely dissolved, the material is considered to be in the solutionized or solution-annealed condition (for example, Type 6061-T4). In order to harden the material, it is subjected to a thermal treatment (aging) in which the material is precipitated. This treatment is conducted at 350° F for about 8 hours for Type 6061.

6-155. If material in the aged condition (Type 6061-T6) is heated to more than 350° F, the precipitated particles grow, or agglomerate, and the hardness is reduced; the material then becomes over-aged. If Type 6061 is heated to 775° F for two to three hours, it becomes soft and is in the annealed condition (Type

6061-0). The tendency toward cracking in aluminum alloys, as a result of welding, increases as the hardness increases. Therefore, when welding under restraint, Type 6061-T6 tends to crack more readily than Type 6061-T4. However, under the same conditions, Type 6061-T4 tends to crack more readily than Type 6061-0.

6-156. Because of the possibility of cracking in hardened aluminum alloys, (either the heat-treatable or nonheat-treatable types) it is permissible to preheat these materials at 700° F; this temperature shall be maintained during welding.

6-157. This preheat, however, may soften the nonheat-treatable grades by removing the cold work, and soften the heat-treatable grades by removing cold work and over-aging the material.

6-158. Similarly, the heat of welding and post welding stress-relieving treatments at temperatures above the aging temperatures will most generally result in softening the material.

6-159. Hardness cannot be recovered in the nonheat-treatable grades. In the Type 6000-series alloys, if the welded structure can be resolutionized and aged by heat treating, the material can be returned to the T-6 condition, and joint efficiencies of 100% can be obtained.

6-160. High-speed processes are desirable wherever possible in welding heat-treated aluminum parts, in that the amount of heat flowing into the base metal to the joint is limited.



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## APPENDIX I

### QUALIFICATION PROCEDURE FOR INSPECTION PERSONNEL

#### A-1. QUALIFICATION PROCEDURE FOR INSPECTION PERSONNEL.

A-2. GENERAL. This appendix describes qualification and certification requirements for personnel engaged in the ultrasonic and eddy current inspection of welds in high pressure and cryogenic systems. The information pertaining to qualification and verification requirements for inspection personnel is based on recommendations by the Technical Council of the Society for Non-Destructive Testing.

A-3. CLASSIFICATION OF PERSONNEL. Ultrasonic and eddy current inspection personnel shall be divided into four classifications of capability.

A-4. Class I Personnel. Class I personnel shall be capable of and have the following qualifications:

- a. Establish techniques for the operation of testing equipment.
- b. Interpret specifications and codes.
- c. Designate the particular tests and best methods and techniques to be used.
- d. Interpret and evaluate results in terms of existing codes and specifications as well as having required experience in engineering design stress analysis and metallurgy to establish acceptance criteria when that criteria is not available.
- e. Sufficient technical knowledge of other commonly-used non-destructive testing methods such as radiography, magnetic particle, and liquid penetrant.
- f. Have the capability of organizing, administering, and grading qualification examinations for Class II and Class III personnel.

A-5. Class II Personnel. Class II personnel shall be capable of and have the following qualifications:

- a. Direct and perform inspection methods in compliance with the applicable specifications.
- b. Calibrate test equipment and accessories.
- c. Evaluate test results and methods as to compliance with the applicable specifications.
- d. Have a knowledge of the scope and limitations of testing methods and the ability to apply detailed testing; techniques to products or parts within the limits of this knowledge.

A-6. Class III Personnel. Class III personnel shall be capable of and have the following qualifications:

- a. Experience, training, and knowledge to operate required test equipment and accessories satisfactorily.
- b. Perform all testing under the direction and supervision of Class I or Class II personnel.

A-7. Class IV Personnel. Class IV personnel shall be capable of and have the following qualifications:

- a. Experience, training and knowledge to observe and follow instructions for handling equipment and techniques used for inspections.
- b. Aid in conducting inspections performed by personnel of higher classification.

#### A-8. EDUCATION AND EXPERIENCE QUALIFICATIONS.

A-9. Class I Personnel. Class I ultrasonic and eddy current inspection personnel shall have educational requirements and experience as follows:

- a. Be a high school graduate.
- b. Be a graduate of a four-year or more engineering or science college, or equal technical experience in this field of non-destructive testing.
- c. Attain a Class II classification for non-destructive testing and inspection in radiography, magnetic particle, and liquid penetrant methods of inspection.
- d. Have experience in non-destructive testing at a Class II classification for a minimum of two years.

A-10. Class II Personnel. Class II ultrasonic and eddy current inspection personnel shall have educational requirements and experience as follows:

- a. Be a high school graduate.
- b. Complete two years college or equivalent experience in engineering or science.
- c. Have experience in non-destructive testing for a minimum of two years.

A-11. Class III Personnel. Class III ultrasonic and eddy current inspection personnel shall have educational requirements and experience as follows:

- a. Be a high school graduate.
- b. Successful completion of a 40-hour training course in ultrasonic testing and eddy current inspection.
- c. Six months as Class IV trainee.

A-12. Class IV Personnel. Class IV ultrasonic and eddy current personnel shall meet the following requirements:

- a. Be a high school graduate.
- b. On-The-Job-Training.
- c. Ability to graduate to Class III after six months training in ultrasonic and eddy current inspection.

#### A-12. EXAMINATION AND CERTIFICATION OF PERSONNEL.

A-13. Technical qualifications for certification of Class I, Class II, and Class III non-destructive ultrasonic and eddy current inspection personnel, shall be determined by qualifying as to vision, general and specific written examinations, and by practical demonstration. Class IV personnel shall be required to pass the vision test in accordance with instructions contained in paragraph A-14 only.

#### NOTE

Qualifying agencies may, during the two year period immediately following the date of this technical order, allow credit for experience and training when the qualifying agency is assured that experience and training of personnel applying for certification is equivalent to requirements stated herein, and which will exist after this technical order has been in force. Examinations described as follows shall be required.

A-14. Vision Examination. The applicant for certification must pass an examination for vision to assure natural or corrected near distance acuity such that the applicant is capable of reading J-1 alphabetical letters on standard Jaeger's test-type chart for near vision or equivalent test-type chart. Vision shall be checked annually.

A-15. General Written Examination. The applicant for certification must successfully pass a general written examination of questions selected at random from a master list of questions with answers. These questions cover basic test principles.

A-16. Specific Written Examination. The applicant for certification must successfully pass a specific written examination of questions covering specific test equipment, operating procedures, and test techniques which may be encountered in a specific assignment. This examination will include questions covering applicable specifications and codes.

A-17. Practical Demonstration. The applicant for certification must successfully demonstrate familiarity with and operation of necessary test equipment and be able to adequately analyze test results. The applicant must test and analyze a sufficient number of test parts to demonstrate capability.

A-18. GRADING OF EXAMINATIONS. Initial Class I non-destructive testing inspector examination will be graded by a responsible ultrasonic and eddy current testing laboratory representing the qualifying agency. All examinations will be corrected and graded by a Class I non-destructive testing inspector representative of the qualifying agency. Examinations shall not be returned to any applicant. In the event that the applicant fails the written examination, grading personnel will review the examination with the applicant within 30 days. All examination information shall be considered of a confidential nature.

A-19. RE-EXAMINATION. A delay of 90 days shall elapse after review of the examination before an applicant, who has failed the examination, can be re-examined.

A-20. QUALIFYING AGENCIES. Qualifying agencies for Class II and Class III personnel shall consist of the employers of non-destructive testing personnel. The qualifying agencies engaged in certifying non-destructive testing personnel shall establish written procedures covering all phases of certification.

A-21. CERTIFICATION RECORDS. When an applicant has qualified as a Class I, Class II, Class III, or Class IV non-destructive testing inspector (in ultrasonics and/or eddy currents) a certifying paper shall be prepared and signed by an authorized representative of the qualifying agency. The certifying paper and all examination papers and records pertinent to qualifications shall be made a permanent part of the personnel record of the applicant. The

applicant shall be furnished with a signed copy of certifying paper. Certifying papers issued to Class I, Class II, Class III, and Class IV, non-destructive testing personnel shall be automatically revoked upon termination of employment for any reason with each employer. Previous experience and certification shall be considered when application for re-examination and re-certification is made with a new employer. The certifying paper for successful applicants shall read as follows:

“Date \_\_\_\_\_

This is to certify that (name of applicant) employed by (name of employer) has successfully completed examinations as a Non-Destructive Testing Inspector on (date) and is hereby de-

signed as a Class (Class - I, II, III or IV) Non-Destructive Testing Inspector in ultrasonics and/or eddy currents, and is authorized to perform duties as a Class (Class) Inspector in accordance with provisions of T.O. 00-25-224.”

A-22. RECERTIFICATION. The qualifying agencies shall re-examine and certify Class I, Class II and Class III personnel at periodic intervals to assure inspection procedures are progressing with the state of the art. The period interval shall be specified in a written procedure established by the qualifying agency. Personnel may be re-examined and have certifying papers extended or revoked at any time at the discretion of the examination representative or the qualifying agency.



## APPENDIX II

### CHARACTERISTICS IN SCREEN PATTERN REFLECTING DISTURBANCES

#### B-1. CHARACTERISTICS IN SCREEN PATTERN REFLECTING DISTURBANCES.

B-2. Characteristics in screen pattern reflecting disturbances are divided into six groups.

- a. Electrical disturbances.
- b. Disturbances from transducer.
- c. Disturbances from surface of inspected part.
- d. Disturbances due to refraction.
- e. Disturbances due to shape of inspected part.
- f. Disturbances due to grain structure of inspected part.

#### B-3. ELECTRICAL DISTURBANCES.

B-4. Noise. With the evidence of noise, the time base or sweep is widened and appears fuzzy on the cathode-ray tube display. This indication may be caused by worn silverplating or crystal defect in the coaxial cable, by contaminated plug contacts, or by a poor ground connection. The indication may also be the result of a defective tube in the high frequency pulse amplifier. Vertical oscillating transient indications occur when electrical devices such as welding equipment are being operated in the vicinity. This will cause a fleeting indication to appear on the cathode-ray tube display. When automated systems are used it can trigger these erratically.

B-5. HORIZONTAL OSCILLATIONS. Horizontal oscillations can be caused by serious line fluctuations, particularly when electric ovens or welding transformers are used in the vicinity of the inspection area. The condition can only be eliminated by using an alternate power source. Horizontal oscillations can also be caused by a defective thyatron in time base or the transmitter circuit of the equipment. These defects are easily verified because they are not synchronous with the time base.

B-6. DAMPING EFFECT. When materials having a very slight damping effect are tested, reflection irregularities may occur when the first sound pulse is not yet completely dampened before the second pulse begins. These reflections are recognized because the reflections can be moved through and in front of the transmitting pulse. These reflections are eliminated by decreasing the sensitivity.

#### CAUTION

While the use of all ultrasonic equipment meets the requirements of the Federal Communications Commission, ultrasonic equipment should not be used when telemetering is in progress in the vicinity.

B-7. DISTURBANCES FROM TRANSDUCER. Disturbances from transducers will occur mainly in combined transmitter-receiver type transducers.

B-8. REFLECTIONS FROM PLEXIGLAS PART OF ANGLE TRANSDUCERS. Reflections from the plexiglas part of an angle transducer occur immediately after the transmitting pulse and remain on the viewing screen when the transducer is not in contact with the part being inspected. While these disturbances can be lessened they are inherent to the ultrasonic system. (See Figure B-1).

B-9. PARTIALLY BONDED PIEZOELECTRIC DISCS. Partially bonded piezoelectric discs often give disturbances which fill the entire cathode-ray tube

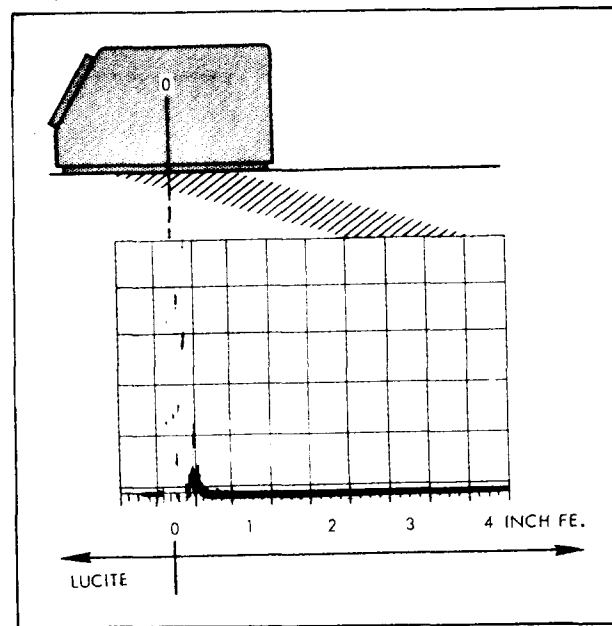


Figure B-1. Maximum Inherent Disturbances in Angle Transducer

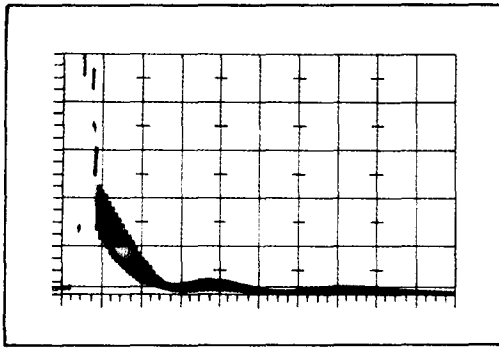


Figure B-2. Indication of Loose Crystal

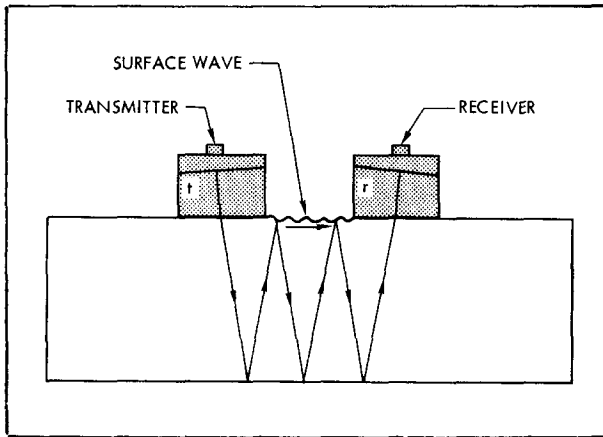


Figure B-3. Surface Wave Coupling Between Separate Transmitter and Receiver Transducers

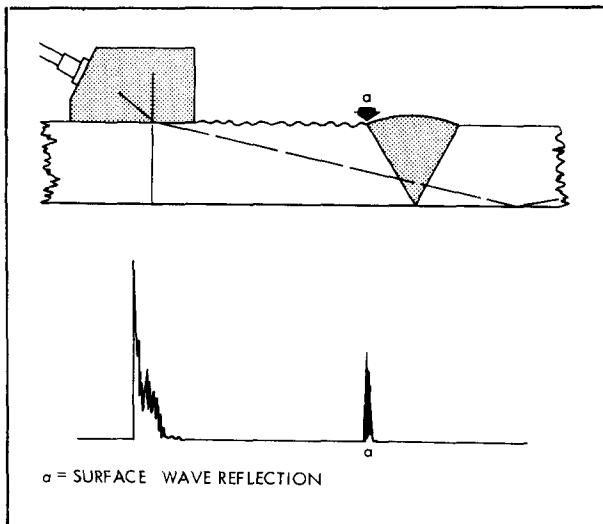


Figure B-4. Disturbances Due to Surface Waves

display. These disturbances arise because a loose crystal vibrates freely and is not dampened out. To test crystals without a protective coating, the crystals should be placed on a piece of fine wire mesh to insure electric contact without damping due to pressure against the material. Repair of crystals, where possible should be made by the manufacturer (See Figure B-2).

**B-10. SURFACE OF INSPECTED PART DISTURBANCES.** The surface finish of the inspected part has considerable influence in causing disturbances, because finish grooves on the surface tend to coincide with the wave length. This disturbance is overcome by placing separate transmitter and receiver transducers parallel to the direction of machining. The use of grease as a couplant is advised when using a single transducer. The same effect occurs in immersed scanning. Grease the surface of the inspected part to eliminate the disturbance. When separate transmitter and receiver transducers are used during inspection, direct coupling across the surface of the inspected part can occur. The direct coupling indication is recognized because the location of the indication changes when the transducers are moved in relation to each other. Placing a thin plastic sheet between transducers and material will overcome this disturbance (See Figure B-3).

**B-11. REFLECTED SURFACE WAVE DISTURBANCES.** Reflected surface waves can give reflections which may be misleading. The surface wave illustrated in Figure B-4 reflects from a weld bead. Movement of the transducers changes the length of the sound path and the disturbance as such is readily recognized, especially when the calculator is used, as described in paragraph 4-93. Placing a thin plastic sheet between transducers and material will overcome this disturbance. However, this phenomenon offers the possibility of crack detection by using a transducer generating only surface waves. The origin of the reflection is determined by moving the transducer so that the transmitting pulse and the defect reflection coincide. With this coincidence the source of the reflection is directly beneath the transducer. Another procedure for validating reflected surface waves, that will dampen or absorb the wave energy, consists of placing a finger wetted with the couplant on the material surface where the waves are inherent. This is also useful with surface wave transducers to determine the location of the indication.

**B-12. DISTURBANCES BECAUSE OF REFRACTION.** Under certain circumstances longitudinal waves may be transformed into transverse or shear waves due to refraction (See Figure B-5). This disturbance occurs near edges such as in rolled stock. Part of the diverging sound beam strikes the side of the inspected part at a relatively shallow angle. In addition to reflection of the longitudinal wave, a transverse wave reflected at a steep angle is generated.



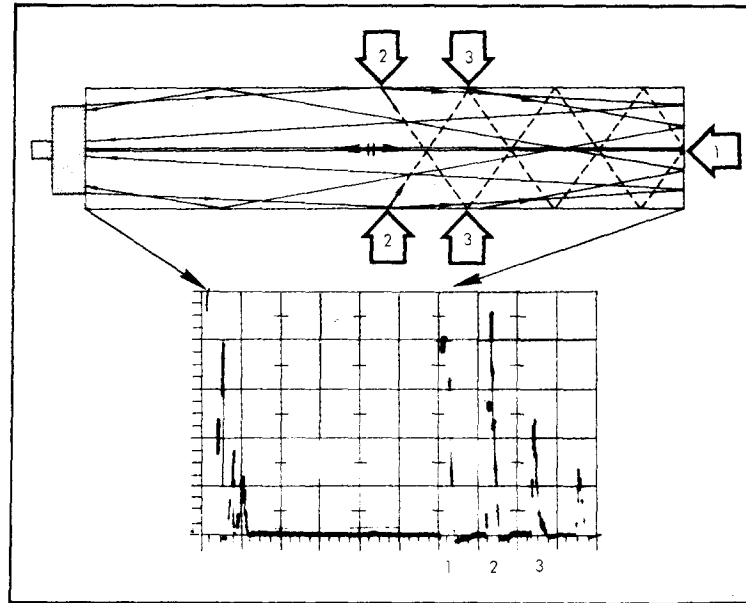


Figure B-5. Disturbance Due to Refraction

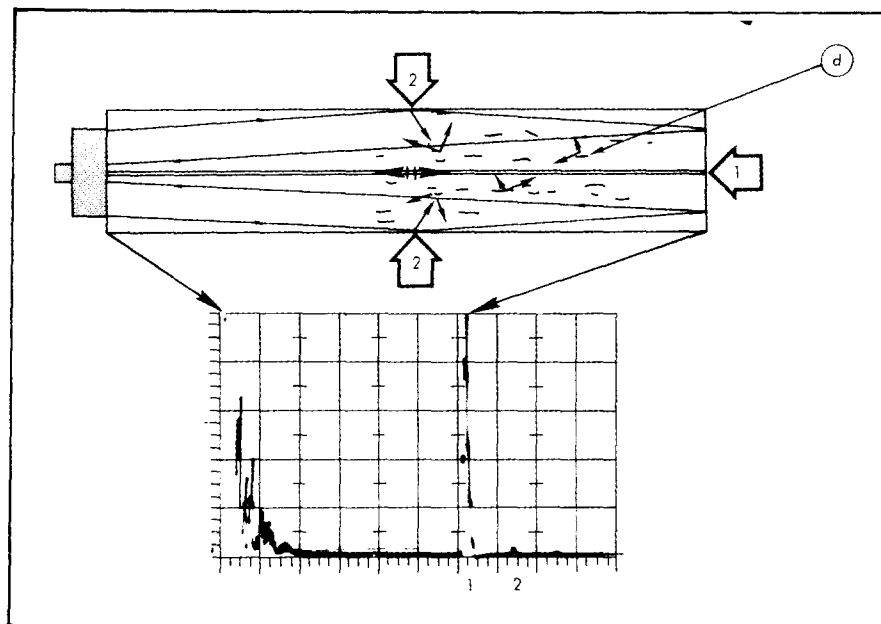


Figure B-6. Interruption of Refracted Waves Due to Defects

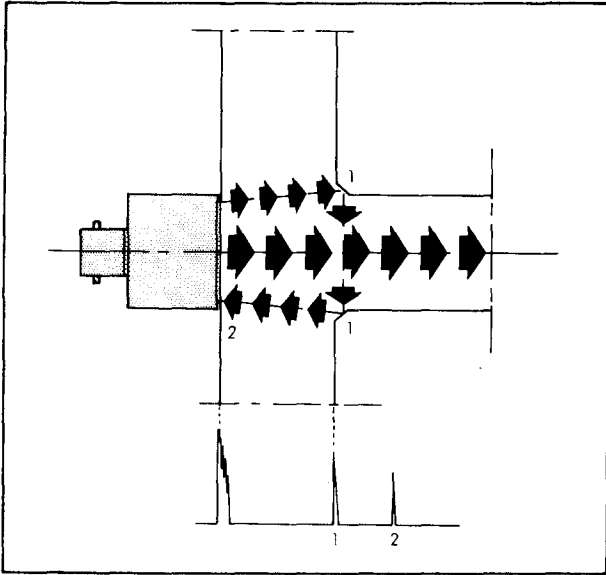


Figure B-7. Disturbances Due to Shape of Part

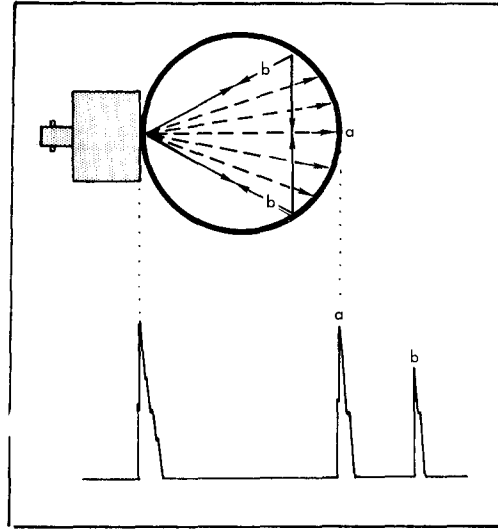


Figure B-9. Reflection Due to Shape of Part

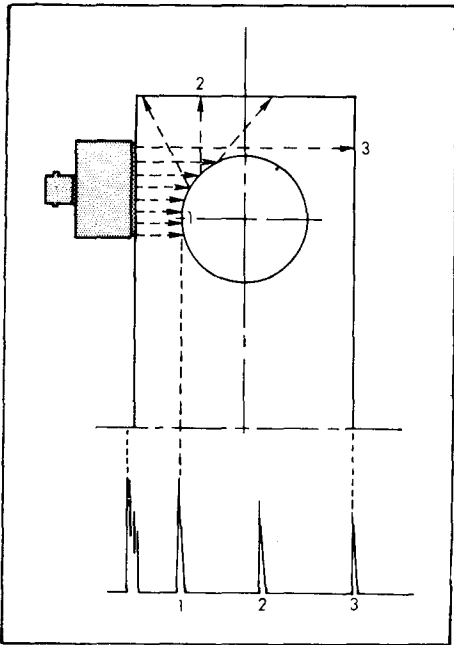


Figure B-8. Indication of a Misleading Reflection

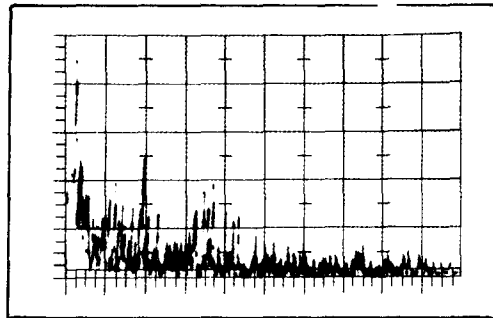


Figure B-10. Irregular Reflections in Coarse Grain Structure

The transverse wave reflects to the opposite wall of the inspected part and the same phenomenon may be repeated. Thus, part of the sound beam is considerably delayed, which is an indication that it will return to the transducer after the main part of the sound beam returns. This phenomenon repeats itself and will cause a series of gradually diminishing reflections after the back reflection. In parts having a simple configuration this effect is not misleading. For example, the effect facilitates inspection of bar stock for the detection of longitudinal defects. Such defects do not give direct reflections because the defects are parallel to the longitudinal sound beam.

Transverse waves are interrupted because the defects are more or less perpendicular to the direction of propagation (See Figure B-6). When transverse reflections do not occur after the first back reflection, further inspection of the part with angle transducers is necessary.

**B-13. DISTURBANCES DUE TO SHAPE OF INSPECTED PART.** When parts having a configuration more complex than rolled stock are inspected, transformation of longitudinal waves into shear or transverse waves may occur, as described in paragraph B-12. For example, during inspection of a railroad axle, the various dimensional changes in the axle may cause transverse waves. It is difficult to recognize transverse waves because reflections will usually occur before the back reflection. Where the inspected part has dimensional changes, a drawing of the part must be made and a theoretical analysis of the path of the sound beam made. The part must be inspected from both sides and the inspection repeated at symmetrical points because such disturbances will occur at all symmetrical points. Other disturbances due to the shape of the part are illustrated in Figure B-7. Figure B-8 illustrates the presence of a misleading reflection at point 2.

**B-14.** Reflections after the first back reflection can occur in diametrical testing of bar stock due to excessive divergence of the sound beam when the transducer is not adapted to the curvature of the part under inspection. Figure B-9 illustrates this reflection as shown at point "b". The contact area will be practically in a straight line and the spread of the beam almost 180 degrees. These disturbances are more likely to occur with increased smoothness

of the surface finish. These disturbances also occur during immersed scanning but are less pronounced. The absence of these reflections after the back reflection may be a direct indication of defects such as described in paragraph B-12. For the inspection of parts having complex configurations, the following procedures should be followed:

- a. Make a drawing of the part and sketch the sound path.
- b. Make a note of the symmetrical occurrence of the reflections.
- c. Measure from other surfaces with angle transducer if possible.
- d. Determine the exact location of the suspected defect with the aid of a reference block or calculator. (Refer to paragraphs 4-89 and 4-91.)

**B-15. DISTURBANCES BECAUSE OF GRAIN STRUCTURE OF INSPECTED PART.** Irregular reflections resulting from coarse-structured parts may occur because the grain structure of part greatly influences acoustical properties of the part. Fine grain structure in steel has a very low damping effect which is contrary to a casting having coarse structure. It is very difficult, if not impossible to transmit ultrasound through such a part. The direction in which the sound beam is sent into the part also influences the reflections due to the orientation of the grain structure. Disturbances due to structure first manifest themselves by producing insufficient sound transmission so that a back reflection is not received, and the sensitivity for detection of a flaw is absent. The lack of sensitivity for detecting a flaw is not misleading because multiple irregular reflections occur as illustrated in Figure B-10. A lower frequency may often give more conclusive results. A sudden change in structure will seldom give a direct reflection unless the area of the change is comparatively large and the shift is radical from fine to very coarse grain structure. During weld inspection considerable damping can be experienced coinciding with multiple small reflections identical to those caused by a coarse structure. Small weld defects will be lost in those small multiple indications.



## APPENDIX III

### INSPECTION OF CASTINGS

#### C-1. INSPECTION OF CASTINGS.

C-2. Due to the structure of castings, ultrasonic inspection of castings is often impossible. When inspecting castings, the frequency and sound velocity should be determined. Sound velocity may vary greatly in different castings. Inspection of castings is not always practical when it is necessary to obtain a frequency of one megacycle as only larger defects can be detected. A back reflection should be obtained if at all possible. Angle transducers or angulation may be used for inspecting non-parallel surfaces by immersion of the part to obtain a direct reflection. Due to the shape and structure of castings, defects in castings generally do not give back reflections. Therefore, the shadow or absorption method of inspection must be used as described in paragraphs 4-74 and 4-75. Inspection of small castings is more difficult because of the following reasons:

- a. Test surfaces are smaller which requires use of special transducers or collimators for contact scanning and special fixtures for immersed scanning.
- b. The small casting is often irregularly shaped.
- c. Reflections are very close and make interpretations difficult.
- d. Comparison with radiographic or destructive tests are necessary. When a small number of castings are to be inspected, ultrasonic inspection is not economical and radiographic inspection is more feasible.

C-3. The following inspection procedures are listed for ultrasonic inspection of castings:

- a. Determine critical areas on the casting and concentrate inspection on these areas.
- b. Determine the best possible position for the transducer or transducers.
- c. Place the transducer in such a position that the transducer and part being inspected are stable and held firmly in position.
- d. Make certain that a good acoustical couplant is used.
- e. Divide the castings to be inspected into three groups according to the amplitude of the back reflection.

f. Inspect one or two castings of each group by another method of inspection such as the radiographic or destructive method of inspection. Various groups of castings can then be classified and a specification for rejection or acceptance of the casting may be established.

g. From each group of castings, a representative casting is selected to adjust and calibrate equipment.

#### NOTE

During the phase of destructive testing, sectioning castings by cutting reveals only limited information. Additional sectioning may be necessary for closer examination of the casting.

C-4. INSPECTION OF INGOTS. A frequency of 1 or 2.25 megacycles should be used during the inspection of ingots. The surface under the transducer should be ground smooth. Inspection should be performed in a transverse direction with a 45-degree angle transducer and a normal transducer positioned as shown in Figure C-2. Detection of secondary pipe in the upper end of the ingot is possible, but small indications should be ignored because the indications may originate from structure. This test is considered to be indecisive.

C-5. INSPECTION OF FORGED AND EXTRUDED PARTS.

C-6. Refer to figure C-1 for a list of inspection possibilities for forged or extruded parts. The most appropriate and best inspection methods for inspecting forged and extruded parts are as follows:

C-7. INSPECTION OF ROUGH FORGINGS. A frequency from 1 to 2.25 megacycles should be used for inspecting rough forgings. The surface must be free of scale and cleaned with a steel brush or emery wheel at surfaces where transducers are to be placed. The ends of forgings should be cleaned by sawing off or turning or grinding the ends. A viscous oil should be used as a couplant. Inspection may be performed in both a longitudinal and transverse direction while using a 45-degree angle transducer. Inspection will show a general pattern of piping. The back reflection should be kept at an amplitude of full scale if possible. The size of defects near the transducer should not be over-estimated while inspecting forged castings. Slag streaks can be recognized because they occur in the direction of the grain

of the forging and when scanned in the direction of the grain, reveal only a slight indication if any indication at all. Segregations in forgings are seldom indicated directly, excluding carbide segregations. Carbide segregations are found by accompanying slag inclusions. Flakes may be distinguished from slag streaks because flakes vary rather abruptly in distance from the surface of the forging when the transducer is moved. If the area of flakes exceeds half a square inch, the back reflection will attenuate intensely and the depth position will change rapidly. However, if flakes occur in concentric rings, it is difficult to distinguish the flakes from slag streaks. When a longitudinal or transverse crack is present and extends in the direction of sound, the amplitude of the back reflection decreases considerably without an essential defect reflection. If the transducer is shifted laterally, the blurred defect reflection usually extends to a considerable depth.

**C-8. INSPECTION OF MACHINED FORGINGS AND PARTS.** The surface of machined parts is usually sufficiently smooth for inspection by ultrasonic inspection without further preparation. However, turning grooves may cause erratic indications. These erratic indications can be overcome by using grease or a viscous oil as a couplant. For immersed scanning, the grease or oil must be applied to the surface

before submerging the part. The frequency used for inspecting machined forgings and parts should vary from 2.25 to 5 megacycles. Inspection is performed by the direct method or by the direct method at increased range. In many cases the shape of the machined forging is complicated and inspection must be performed with extreme accuracy. It is often necessary to examine forgings without obtaining a clear pattern but the asymmetry of the pattern in a symmetrical part will be an indication of defects. Figure C-3 illustrates basic test problems with correct and incorrect methods of inspection. Plane surfaces are preferred for inspecting machined forgings because of better surface contact and because refraction during immersed scanning is eliminated. For large machined parts such as axles, the following general rules should be followed:

- a. Determine the best inspection method from a drawing of the part to be inspected. Make a sketch of the drawing in ratio to the screen pattern. Place the sketch above the oscilloscope to facilitate identification of various reflections.
- b. Determine the frequency and size of the crystal. Use a collimator if the part is to be immersed.

FORGED OR EXTRUDED PARTS	DEGREE OF INSPECTION	REMARKS
Ingots	Limited	Inspection depends upon structure and alloy used.
Rough Forging	Limited	Heat treatment may be required. Inspect initially for large defects such as shrink holes, disc-shaped cracks, and disintegration due to forging.
Machined Forgings and Parts	Good	Inspect for defects such as shrink holes, disc-shaped cracks, hydrogen cracks, and small flaws.
Shrink Fits	Good	Inspection is usually limited to new parts where oil and grease have not penetrated the shrink fit.
Rolled Stock	Good	Inspect laps and seams. Inspect for cracks.
Plates and	Good	Inspect for slag inclusions, laminations, and wall thickness measurements.
Rivet Hole Inspection	Good	Inspect for incipient cracking and web cracks.
Extrusion	Good	Inspect for longitudinal defects and inclusions.

Figure C-1. Inspection of Forged and Extruded Parts

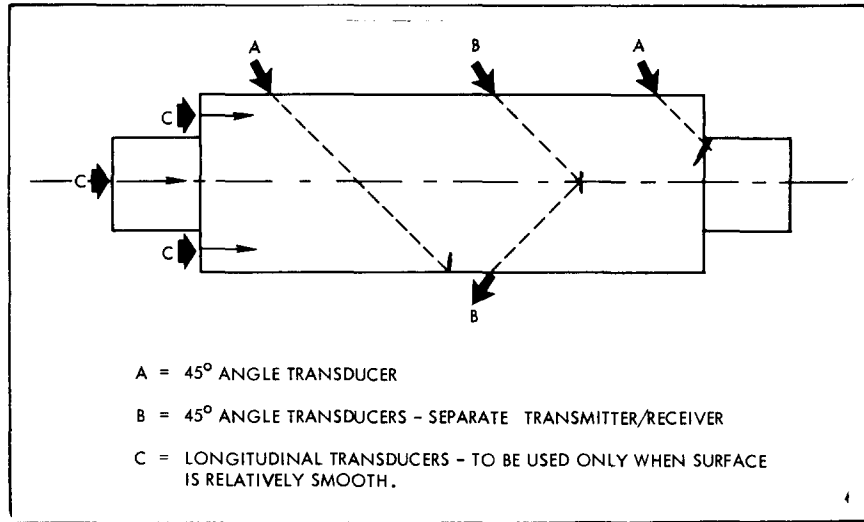


Figure C-2. Position of Transducer When Inspecting Ingots

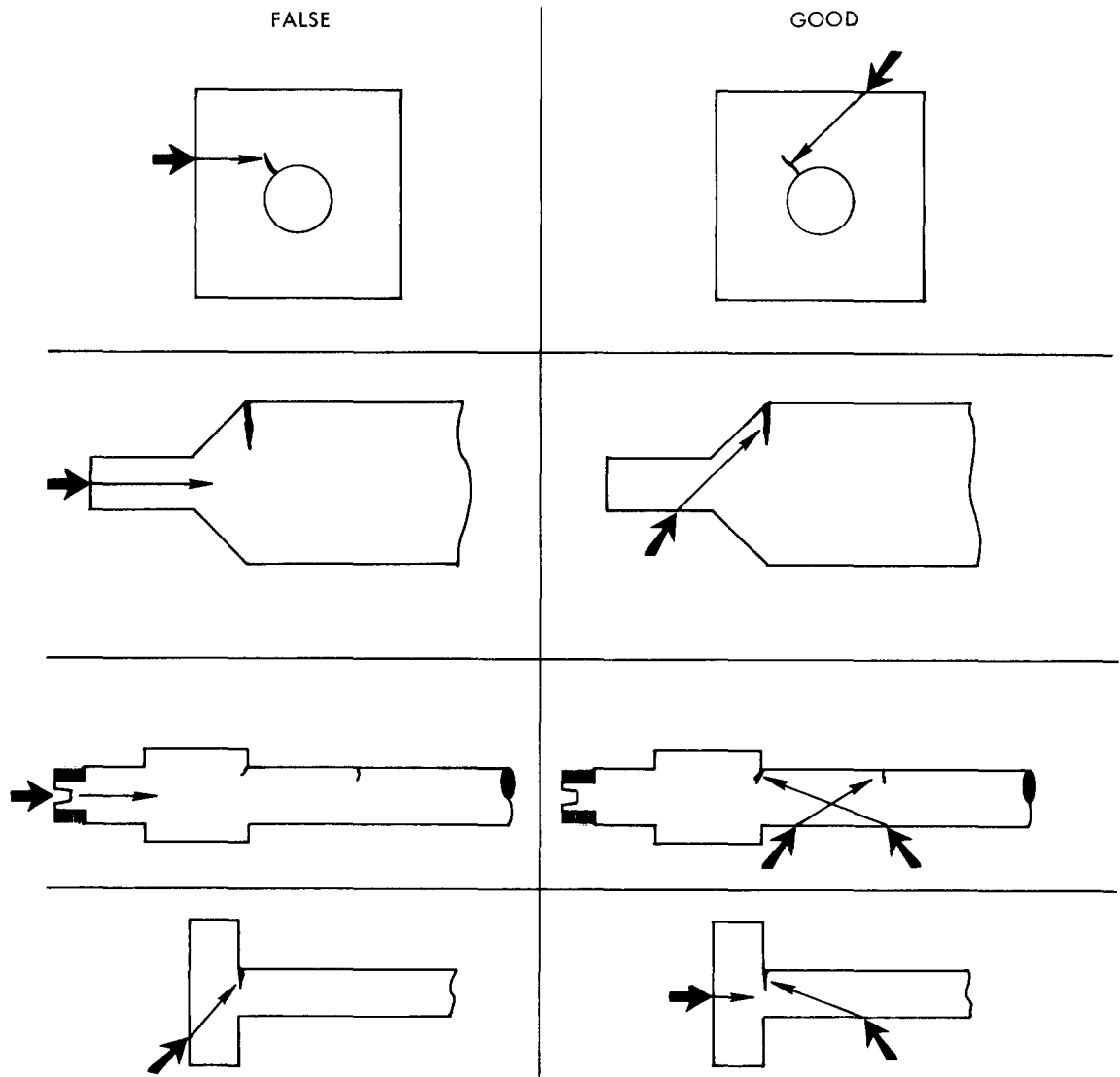


Figure C-3. Basic Test Problems with Correct and Incorrect Methods of Inspection

c. Transmit the sound at a slight angle without changing the longitudinal waves into transverse waves if possible, retaining the angle at less than 33 degrees in steel.

d. Determine the exact location of the back reflection.

e. Adjust the sensitivity with the back reflection or with the aid of a reference block. (Refer to paragraph 4-49).

f. When inspecting axles, always inspect from two sides of the axle and determine the location of reflections accurately because the reflections may coincide with dimensional changes.

g. Inspect with an angle transducer.

h. Examine for symmetry in the screen pattern and in the part.

i. Be alert for delayed reflections due to changes in dimensions and defects. The delayed reflections may be due to transformation from longitudinal into transverse waves.

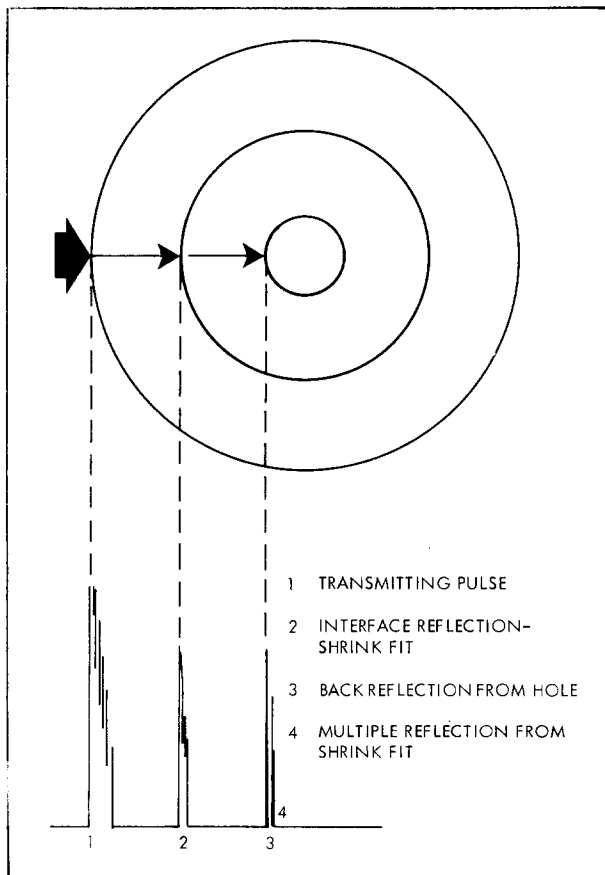


Figure C-4. Shrink fit with Accompanying Screen Pattern

j. Indicate defects or suspected reflection on the sketch of the part.

k. Correlate findings with other non-destructive methods of inspection such as magnetic particle or liquid penetrant, if possible. Immersed scanning is best used for inspection of gear wheels where incipient cracks can be expected on gear teeth. Miniature contact transducers give excellent results for inspection of parts having this type of configuration.

### NOTE

Auxiliary equipment is required for immersed scanning, particularly of symmetrical parts where an adjustable turntable should be used.

### C-9. INSPECTION OF EXTRUSIONS.

C-10. The surface condition of extrusions is appropriate for ultrasonic inspection. Test frequencies of 2.25 to 5 megacycles are used. Methods of inspection are the same as those for rolled stock as described in paragraph C-15 below and machined forgings and parts described in paragraph C-8. When inspecting extrusions, only longitudinal defects can be expected. Immersed scanning is best suited for inspecting extrusions.

### C-11. INSPECTING SHRINK FITS.

C-12. Surfaces become partially permeable to sound when pressed together. The amount of permeability depends upon the pressure exerted on the two materials and the surface condition of the boundary.

Generally it can be said that pressure of 4 kg/mm<sup>2</sup> or 5690 pounds/square inch gives a relative amplitude of the reflection of 15 millimeters at 2-1/4 megacycles, and 50 millimeters (in.) at 5 megacycles.

At a pressure of 8 kg/mm<sup>2</sup> or 11,380 pounds/square inch, this is 35 millimeters (in.) at 2.95 megacycles and 65 millimeters at 5 megacycles. These values are for a smooth boundary surface. From a rough surface, however, the amplitude of the reflection is considerably higher. Figure C-4 shows a shrink fit with accompanying screen pattern. The quality of a shrink fit is roughly classified as follows:

a. Loose shrink fit; many multiple reflections with no back reflection.

b. Moderate shrink fit; many multiple reflections with small back reflections.

c. Good shrink fit; few multiple reflections with sufficient back reflections.

d. Very good shrink fit; practically no multiple reflections with almost normal back reflection.



C-13. When oil exists in shrink fits tested, the oil penetration in a loose shrink fit would make it appear to be a moderate shrink fit, in a moderate shrink fit would appear to be a good shrink fit, and a good shrink fit would appear to be a very good shrink fit. The presence of oil in used shrink fits must therefore be considered.

#### C-14. INSPECTION OF ROLLED STOCK.

C-15. The surface of rolled stock should be clean and dirt and loose scales removed. Test frequencies for inspecting rolled stock must be between 2.25 and 5 megacycles. Angle transducers, with 35-, 45-, and 60-degree angles may be used depending upon the diameter of the rolled stock. Inspection of the stock should be performed in a longitudinal direction first. Transverse defects will show direct reflections. When longitudinal defects are evident, the amplitude of the back reflection will decrease while often transverse defects can be observed after the back reflection. Inspection in a transverse direction will indicate longitudinal defects more distinctly. Core flaws, which occur most commonly as narrow longitudinal piping, cannot be found by inspecting from one direction only. Better inspection can be had by zig-zagging the transducer between two surface lines shifted by 90 degrees. During inspection by immersed scanning stock should be rotated.

C-16. Longitudinal defects, which are eccentric, cannot be found with inspection methods described in paragraph C-12. However, it is possible to receive an indirect indication by the absence of a delayed reflection. When using angle transducers for determining eccentric defects when inspection is performed by immersed scanning, the most successful method is to adjust the transducer away from the center of the stock as illustrated in figure C-5. Any defect will be shown as a moving reflection when the transducer is shifted to a new location or the stock rotated. When the reflection disappears near the transmitting pulse the defect is beneath the

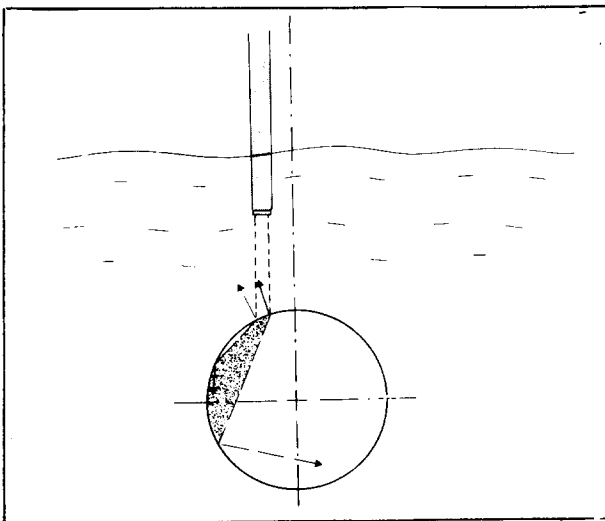


Figure C-5. Immersed Scanning of Bar Stock and Tubes

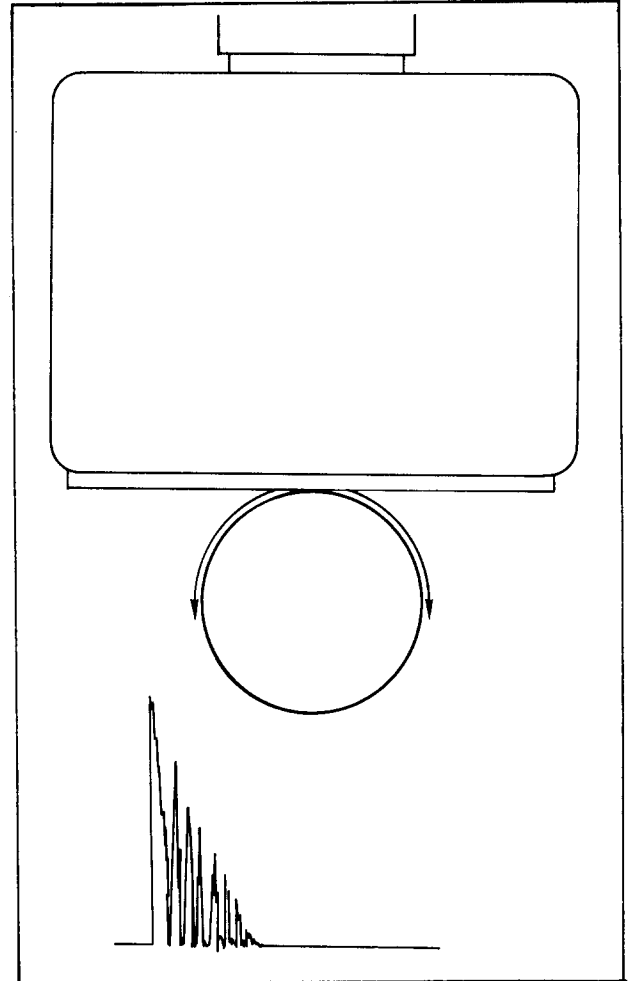


Figure C-6. Surface Wave Inspection of Small Diameter Bar Stock

transducer. When the reflection moves in front of the indication from the surface of the stock in immersed scanning, dirt or surface irregularities may be the cause of the indication. Surface waves can be used for the detection of surface defects. Using surface waves for inspecting stock having small diameters is of special importance. The transducer is placed on the stock as shown in Figure C-6 without the use of a couplant. Strong surface waves are generated around the stock in both directions. The screen pattern will appear as shown in Figure C-6. Any defect will first decrease the number of multiples and secondly give direct reflections.

#### C-17. INSPECTION OF PLATES AND SHEETS.

C-18. Surfaces of plates and sheets must be free of loose scale, dirt, and rust. The test frequency must vary from 2.25 to 5 megacycles. Higher frequencies are used for thinner materials. Plates having a thickness of one inch or more are inspected by the direct method at a range setting of twice the thickness of the material if possible. Laminations will give direct reflections with considerable attenuation of the back reflection or complete disappearance of the back reflection.

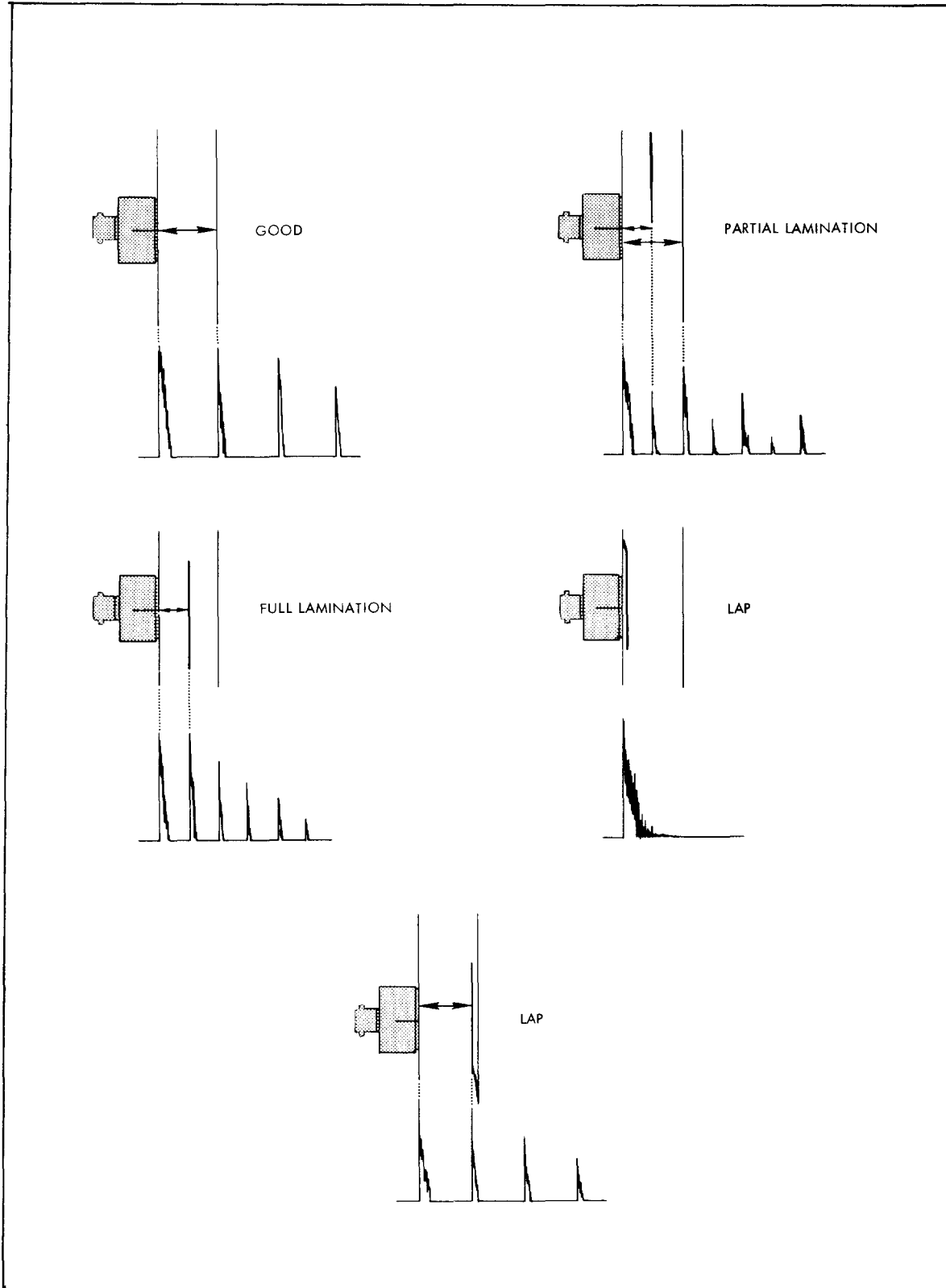


Figure C-7. Ultrasonic Inspection of Plates, Sheets, and Pipes

the back reflection. Slag inclusions will give direct reflections also, but the attenuation of the back reflection is often negligible. Laps on the side of the transducer will cause total disappearance of the pattern but when the lap is on the opposite side of the transducer, a change in location of the back reflection will be observed as shown in figure C-7. The direct method of inspection at an increased range or inspection by the absorption method must be used when inspecting thinner sheets.

C-19. When inspecting plates and sheets by the direct method of inspection, not only is the regularity of the pattern observed, but also defect reflection between the multiples is shown. In the absorption method of inspection, only the regularity of the pattern and the number of multiples are considered. Inspection of plates by using angle transducers is another method of fast inspection. When the sound beam is transmitted perpendicularly to the plate-edge, a reflection can be obtained from it. This reflection is used as a reference indication. Attenuation of this signal can be caused by defects, lack of coupling, or misalignment of the transducer with the plate edge. This method of inspection is used as a fast inspection technique only. Inspection of plates by the direct and absorption methods must be applied for further evaluation of the material. Separate transmitter and receiver angle transducers, spaced at a fixed distance from each other, are preferable for inspecting thin materials. The amplitude of the transmission pulse is a measure for the energy received and the presence or absence of defects.

C-20. INSPECTION OF RIVET HOLES (See figure C-8).

C-21. The surface of the plate near and between the rivets must be free of scale and rust for inspecting rivet holes. Only angle transducers are used; preferably miniature transducers. Frequency for inspecting rivet holes must be 2.25 to 5 megacycles. An 80-degree angle transducer is used for plates thicknesses up to 0.600-inch thick. A 70-degree angle transducer is used for inspecting thicker material. The sound beam is transmitted in the direction of the rivet hole until a maximum reflection is obtained. By changing the direction of the beam, the amplitude of the reflection will decrease. If a crack is present, however, another reflection occurs at the same place. The transducer must be moved 360 degrees around the rivet hole for incipient cracks. However, this is practically impossible. Dangerous cracks usually occur at an angle range of 45 degrees to the connecting line of the rivets and it is therefore possible to check the front row of rivets quite sufficiently. If an accurate test of other rows of rivets is necessary, special miniature transducers must be obtained. It can be calculated whether cracks are on the inside or outside of the material by using the calculator as described in paragraph 4-91. If the cracks are on the outside surface of the material, a magnetic particle inspection or penetrant inspection shall be performed.

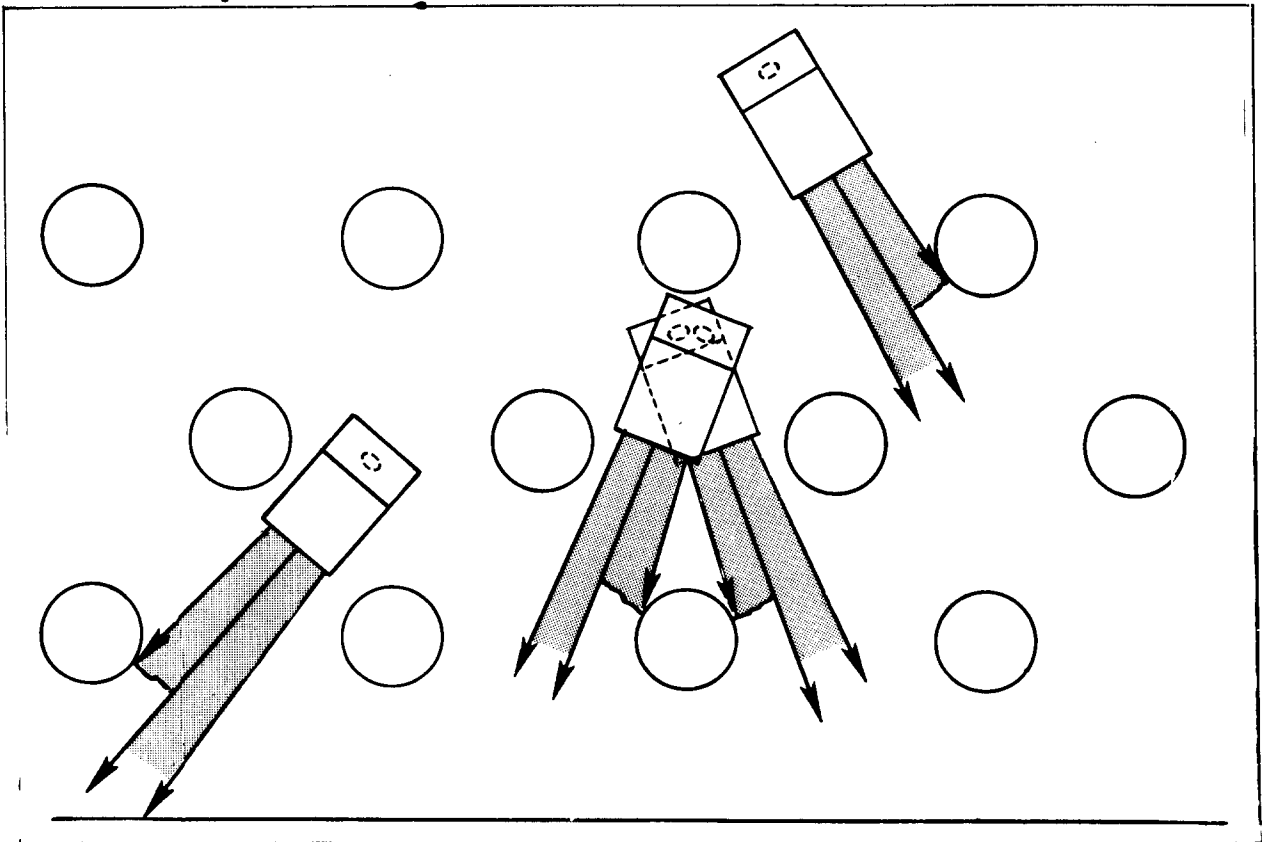


Figure C-8. Inspection of Riveted Joint for Incipient Cracking



## APPENDIX IV

### ULTRASONIC VERSUS RADIOGRAPHIC WELD INSPECTION

#### D-1. ULTRASONIC VERSUS RADIOGRAPHIC WELD INSPECTION.

D-2. The most widely used method of non-destructive testing of welds is radiography; that is X-rays electronically produced or gamma rays emitted by the disintegration of radio isotopes, usually Iridium 192 and Cobalt 60. Radiographic inspection has many advantages but several inherent disadvantages. The major objection in weld inspection is that X-rays and gamma rays are direction sensitive with respect to two-dimensional defects. As these defects are detrimental to the integrity of the weld the objection is a serious one in critical structures. These defects, cracks, lack of penetration and lack of fusion can be detected with ultrasonic techniques. The minimum dimension of detectable discontinuities is approximately 125 percent of the grain size. Figures D-1 and D-2 illustrate the necessity of multiple radiographs in detecting these defects.

Radiographic inspection becomes more and more difficult at greater thicknesses, especially with respect to defects mentioned. The interpretation of radiographs is difficult.

D-3. The ultrasonic method of inspection, particularly at construction sites under adverse conditions with respect to space and danger to personnel, offers many advantages. The ultrasonic methods of inspection are objectionable in some areas; the inspection of welds in materials of less than 0.5 inch is possible, but to determine the depth of a defect under the surface or in many cases, the nature of the defect is difficult to determine. The use of higher frequencies and miniature transducers has improved inspection, however by using these accessories the limiting thickness is between 0.250 and 0.375 inch. Contrary to radiography, the greater the thickness of the material the better the possibilities are for ultrasonic inspection. The fact that a permanent record of the weld is not available with ultrasonic inspection, except photographs of the screen pattern, may also be called objectionable.

D-4. The automation of several ultrasonic techniques has partially overcome the objection of not having a permanent record of the weld inspection, by recording the amplitude of defect reflection on a strip chart. The position and width of the recorded

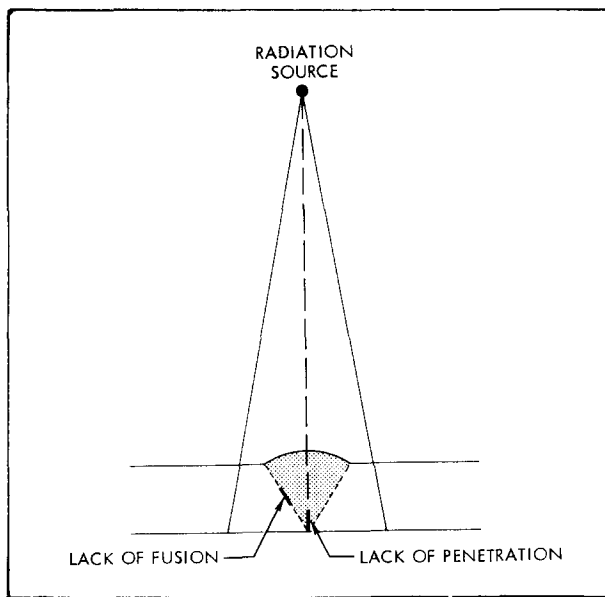


Figure D-1. Radiographic Weld Inspection to Detect Lack of Penetration

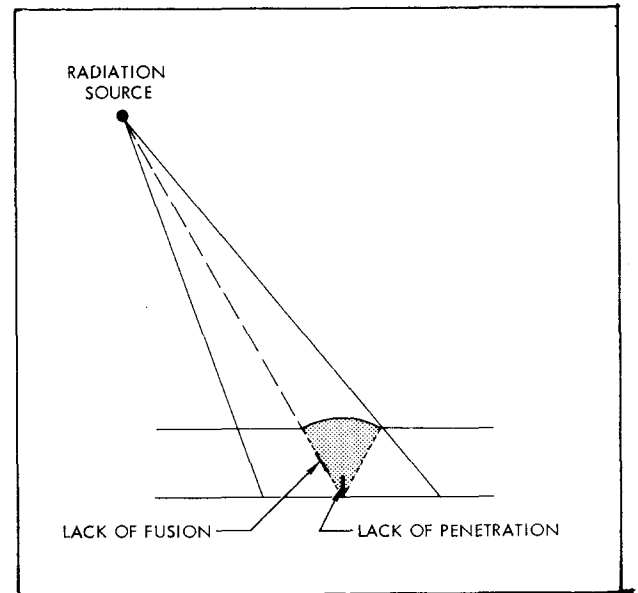


Figure D-2. Radiographic Weld Inspection to Detect Lack of Fusion

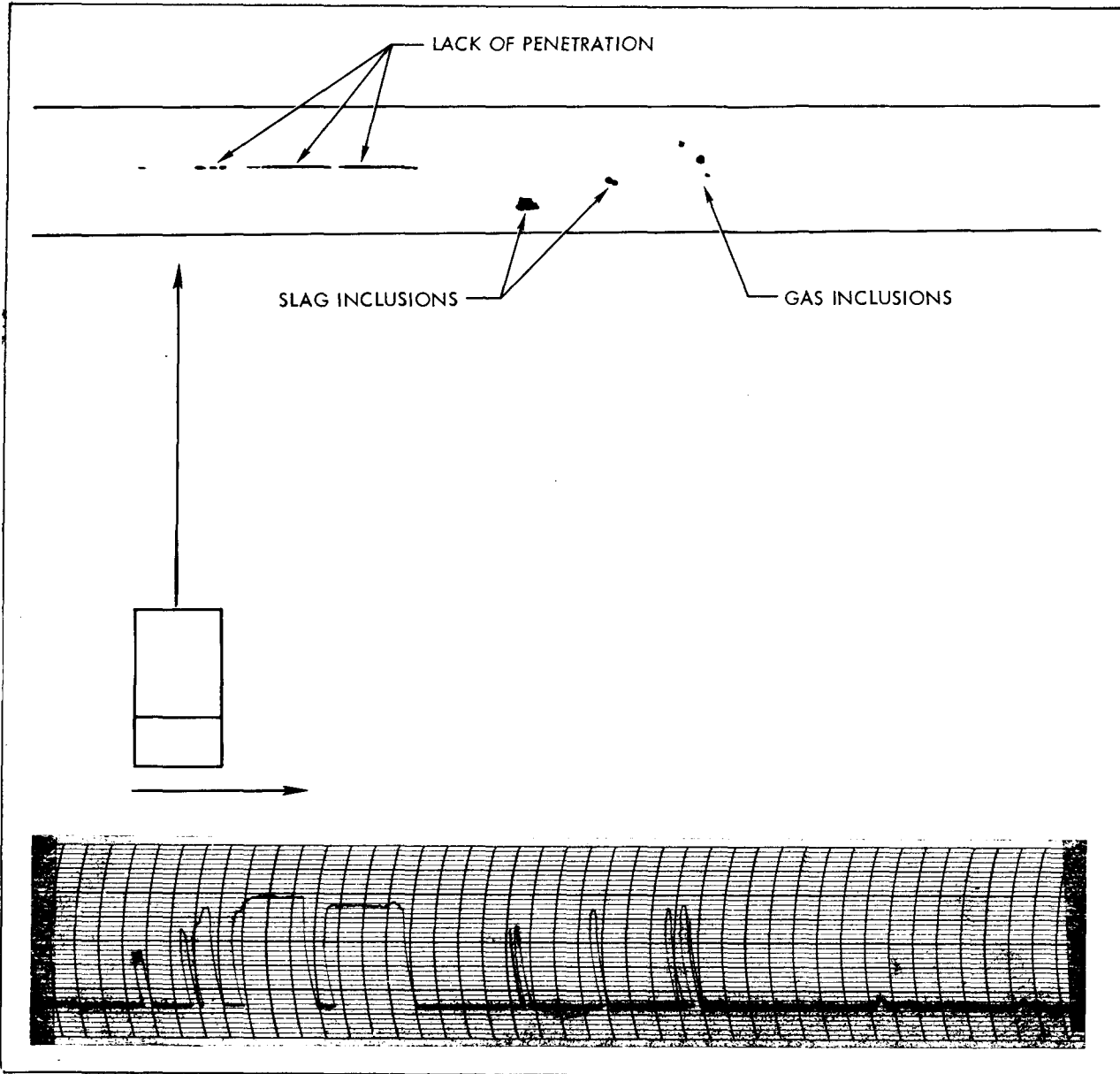


Figure D-3. Comparison of Recorded Indication with Position and Length of Defects

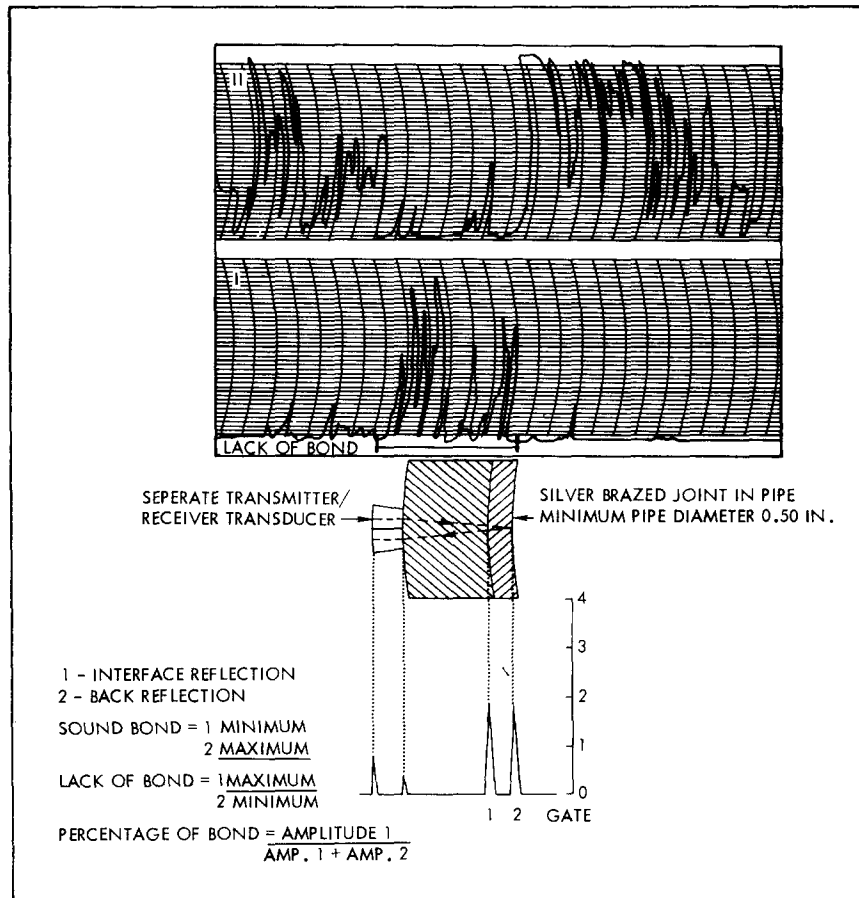


Figure D-4. Recordings of Automatic Ultrasonic Inspection of Silver Brazed Pipe Joints with Ratio Analyzer

indication is relative to the position and the length of the defect (See figure D-3). Figure D-4 shows automatic recordings made of the silver brazed joint in a pipe having a diameter of 0.5 inch. The device also analyzes the percent of bond per transducer area and over an adjustable area such as 1/4-inch of the circumference.

D-5. Personnel performing ultrasonic inspection are evaluating the integrity of the weld by observing a dynamic pattern of reflections. A judgement is made immediately with respect to classification of the weld. Personnel performing radiographic inspection do not evaluate the integrity of the weld from a dynamic pattern, but from a permanent shadow picture. The interpretation does not have to be accomplished immediately but can be postponed to a more convenient time when, if necessary, a group judgement with respect to the classification of the weld can be made.

D-6. In figures D-5 through D-9, a number of possible welds in constructions are illustrated with the optimum inspection method or methods indicated. The symbols used are those given by the American Welding Society in the "Welding Handbook," Fourth Edition, Section 2, Non-Destructive Testing Symbols. (See figure D-10).

TYPE OF TEST	SYMBOL
Radiographic	RT
Magnetic Particle	MT
Penetrant	PT
Ultrasonic	UT
Eddy Current	ET

The test symbol consists of the following elements;

Reference line	(N) number of tests
Arrow	Tail
Basic testing symbol	Extent of test
Test all around symbol	Specification

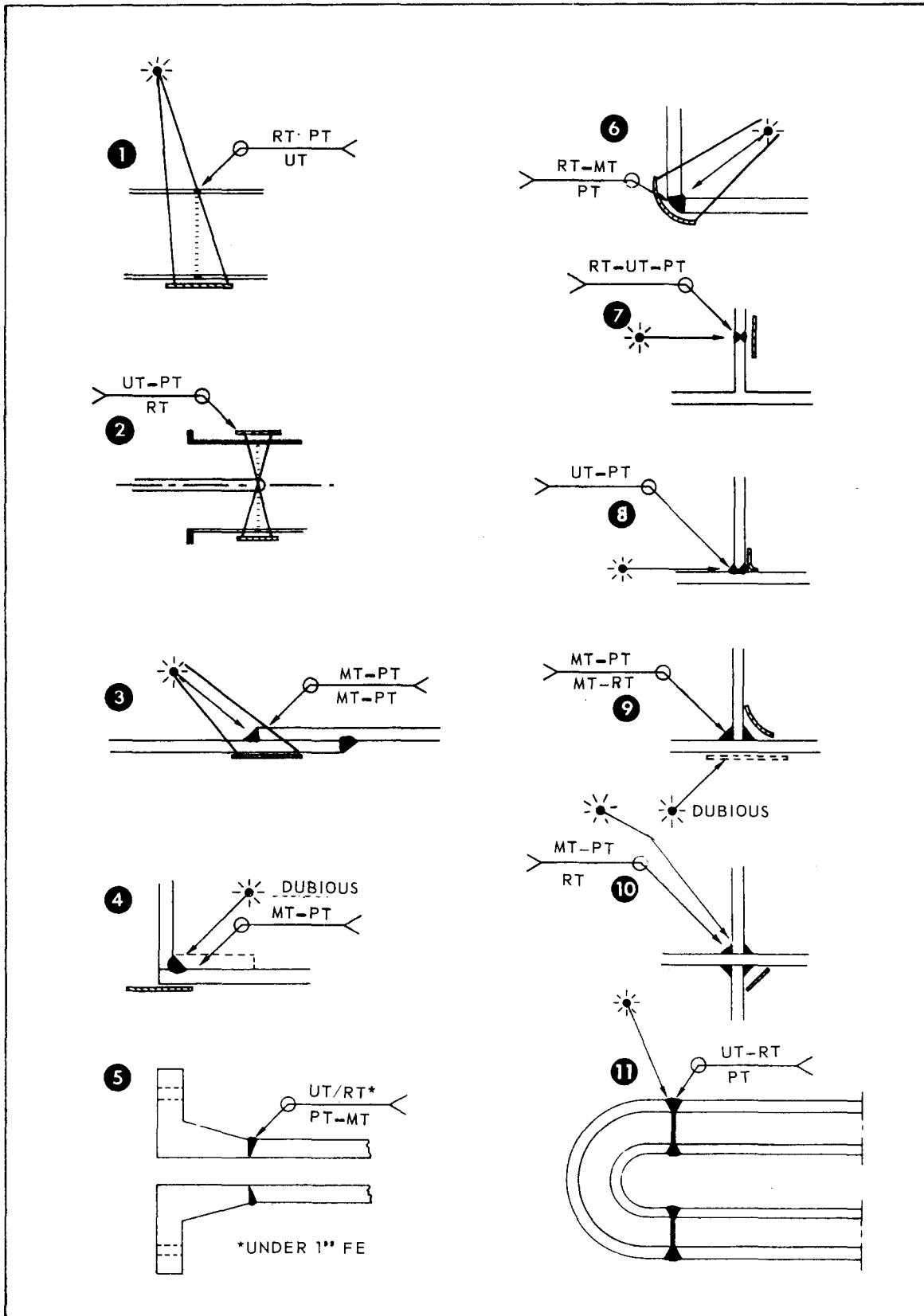


Figure D-5. Possibilities of Inspection



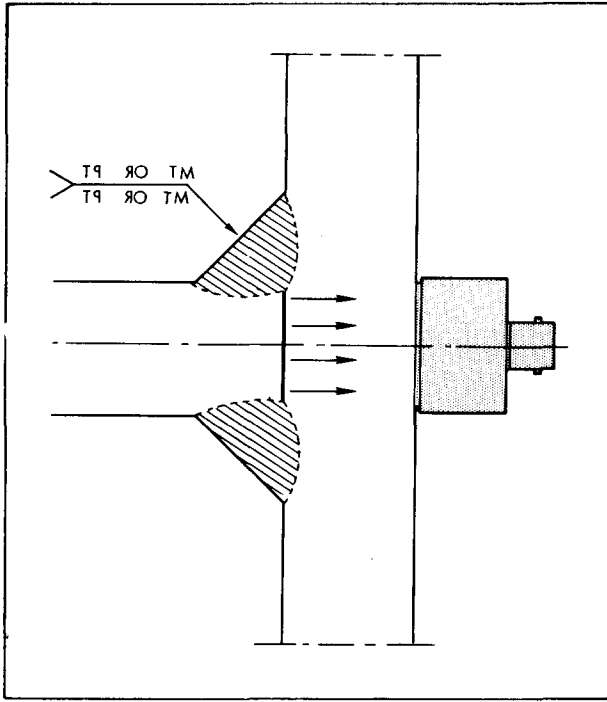


Figure D-6. Possibilities of Inspection

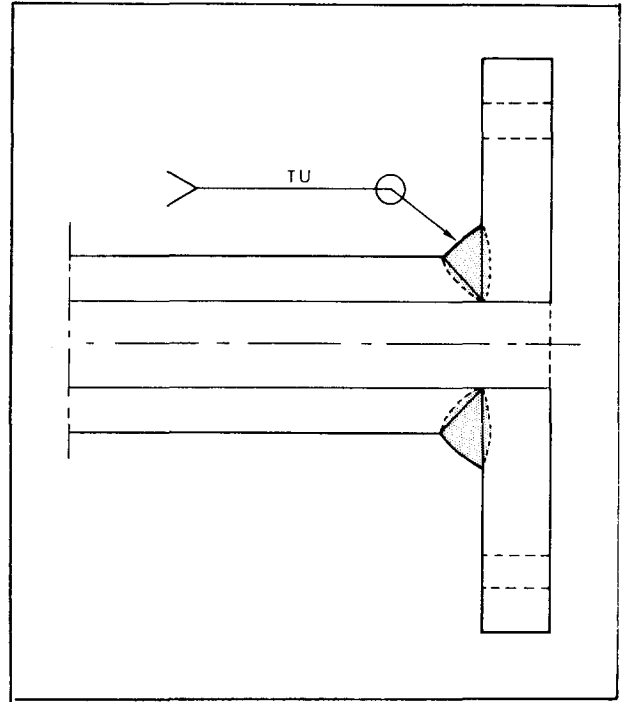


Figure D-8. Possibilities of Inspection

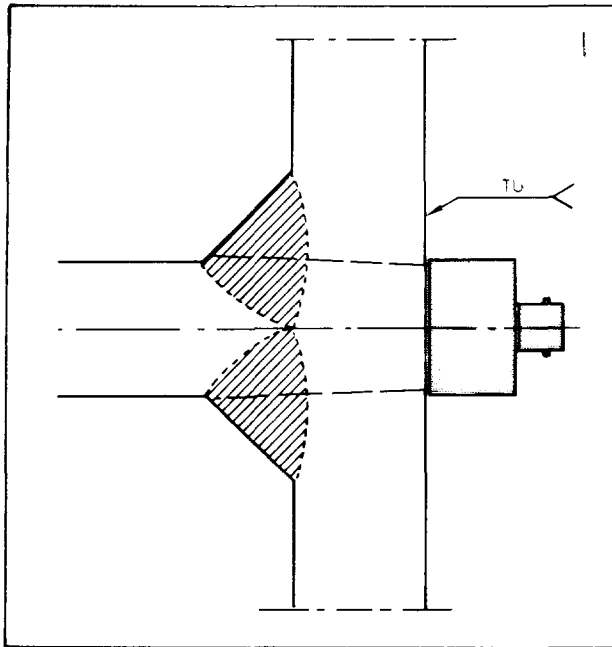


Figure D-7. Possibilities of Inspection

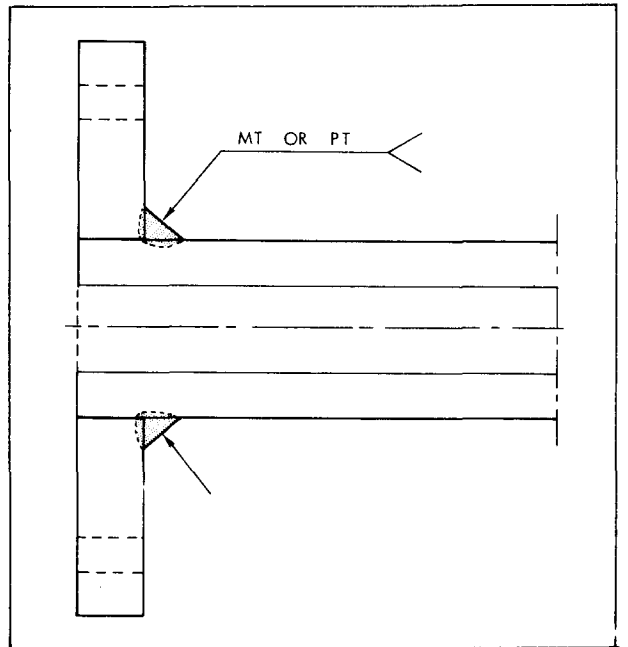


Figure D-9. Possibilities of Inspection

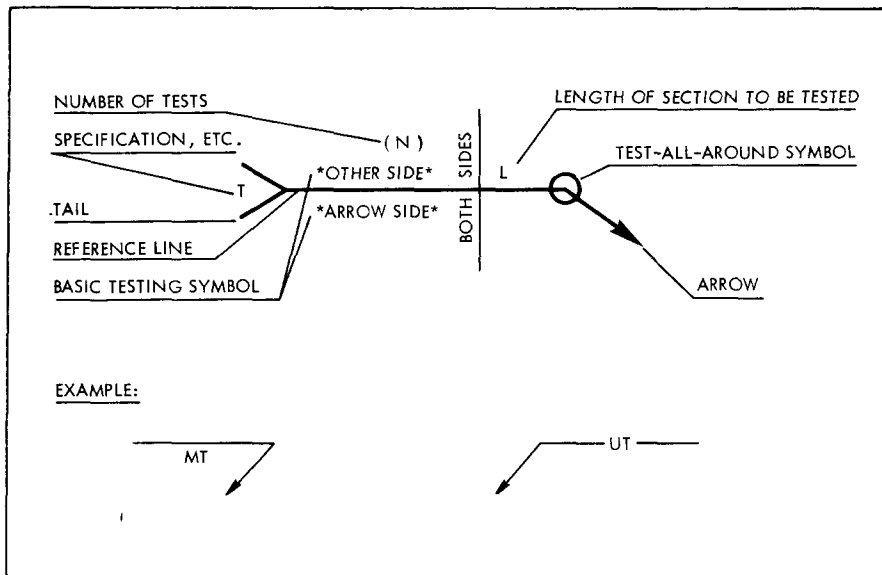


Figure D-10. Basic Testing Symbols According to American Welding Society

## APPENDIX V ENGINEERING TABLES

MATERIAL	LONGITUDINAL VELOCITY $C_L$	TRANSVERSE VELOCITY $C_t$	DENSITY $\rho$	SPECIFIC ACOUSTIC IMPEDANCE $Z$
	METERS/ SECOND	METER/ SECOND	KILOGRAM/ METER <sup>3</sup>	KILOGRAM/ METER <sup>2</sup> - SEC
Air	332		$0.00105 \times 10^3$	$0.0004 \times 10^6$
Aluminum	6320	3130	2.73	17
Basalt	5930	3140	2.72	16
Beryllium	12890	8880	1.8	23
Bismuth	2180	1100	9.8	21
Brass (Rolled)	3830	2050	8.1	31
Cadmium	2780	1500	8.6	24
Cast Iron - Grey	4000-5500	2500-3100	7.2	28-40
Copper	4700	2260	2.9	42
Diesel Oil	1250		.80	1
Glass	5660/4260	3420/2560	2.5	14-15
Glycerine	1920		1.26	2.5
Gold	3240	1200	19.3	63
Gypsum	4970		2.26	11
Ice	3980	1990	0.9	3.6
Lead	2160	700	11.3	25
Magnesium	5770	3050	1.74	10
Manganese	4660	2350	8.4	39
Marble	6150	3260	2.66	16.5
Mercury	1450		13.55	20
Molybdenum	6250	3350	10.2	63.7
Nickel	5600	2940	8.8	50
Oil SAE 30-20	1740		.87	1.5
Plexiglas/Lucite	2730		1.18	3.2
Platinum	3960	1670	21.4	85
Polystyrene	2670		1.06	2.8
Porcelan	5300/5900		2.4	13
Rubber (Soft)	1500		$0.9 \times 10^3$	$1.4 \times 10^6$
Rubber (Hard)	2300		1.2	2.8
Quartz	5570	3515	2.6	14.5
Silver	3600	1590	10.5	38
Steel	5850	3230	7.8	45.6
Tin	3320	1670	7.3	24
Titanium	5990	3120	4.5	27
Tungsten (Wolfram)	5260	2920	19.2	104
Tungsten Carbide	6650	3940	10.0-15.0	66-100
Uranium	3370	2020	18.7	63
Water at 20°	1438		1.0	1.5
Zinc	4170	2410	7.1	30
Zirconium	4650	2300	6.4	30

Figure E-1. Table of Sound Velocities in Solids

CENTIGRADE	METER/SECOND	CENTIGRADE	METER/SECOND
15.0°	1470.60	20.0°	1483.10
15.9°	1471.85	21.0°	1484.35
16.0°	1473.10	21.5°	1485.60
16.5°	1474.35	22.0°	1488.85
17.0°	1475.60	22.5°	1488.10
17.5°	1476.85	23.0°	1489.35
18.0°	1478.10	23.5°	1490.60
18.5°	1479.35	24.0°	1491.85
19.0°	1480.60	24.5°	1494.35
19.5°	1481.25	25.0°	1495.60

Figure E-2. Table of Sound Velocities in Water

EXAMPLE ALUMINUM AND PLEXIGLAS

$Z_2 = 17.0$  (Aluminum)  $Z_1 = 3.2$  (Plexiglas)

$$R_a = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{(17.0 - 3.2)(10^6)}{(17.0 + 3.2)(10^6)} = .683 \text{ or } 68.3\%$$

ATTENUATION IN NEPERS =  $\frac{1}{2} \log_{\epsilon} \frac{W_i}{W_r}$

$$= \frac{1}{2} \log_{\epsilon} \left( \frac{Z_2 + Z_1}{Z_2 - Z_1} \right)^2$$

$$= \log_{\epsilon} \frac{Z_2 + Z_1}{Z_2 - Z_1}$$

$$= \log_{\epsilon} \frac{20.2}{13.8} = \log_{\epsilon} 1.465$$

$$= 0.382$$

1 NEPER = 8.686 DECIBELS

0.382 NEPERS = 3.31 DECIBELS

The following method for calculating decibels may be used when the reflection factor for amplitude in percentage is known.

Thus: Consider the above materials aluminum and plexiglas where  $R_A = 68.3\%$

$$\text{Decibels} = 20 \log_{10} \frac{100}{68.3} = 20 \log_{10} 1.467$$

$$= (20) (0.166)$$

$$= 3.33$$

Figure E-3. Reflection Factors for Amplitude In Percentage and Decibels. (Sheet 1 of 2)

	ALUMINUM	BRASS	COPPER	NICKEL	OIL (SAE 30)	PLEXIGLAS	PORCELAIN	RUBBER (SOFT)	RUBBER (HARD)	SILVER	STEEL	TUNGSTEN	WATER	
ALUMINUM		29/11	41/7.8	49/6.1	84/1.5	68/3.3	13/18	85/1.4	72/2.9	38/8.4	46/6.8	72/2.9	84/1.5	
BRASS			15/17	23/13	91/0.8	81/1.8	41/7.6	91/1.6	83/1.8	10/20	19/14	54/5.4	91/0.8	
COPPER				8/22	93/0.6	86/1.3	53/5.6	94/0.6	87/1.2	5/26	4/27	43/7.4	93/0.6	
NICKEL					94/0.5	88/1.1	58/4.7	94/0.5	89/1.0	13/17	4/28	35/9.0	94/0.5	
OIL (SAE 30)						40/9	80/2	3/30	30/10	92/0.7	94/0.6	97/0.2	0	
PLEXIGLAS							60/4.4	40/8	7/23	84/1.5	87/1.2	94/0.5	40/9	
PORCELAIN								80/2	65/3.8	49/6.2	56/5.1	78/2.2	80/2	
RUBBER (SOFT)									50/6	93/0.7	94/0.5	97/0.2	3/30	
RUBBER (HARD)			PERCENTAGE/DECIBELS								86/1.3	88/1.1	95/0.5	30/10
SILVER											9/21	47/6.6	92/0.7	
STEEL												39/8.2	94/0.6	
TUNGSTEN													97/0.2	
WATER														

Figure E-3. Reflection Factors for Amplitude In Percentage and Decibels. (Sheet 2 of 2)

ANGLES (+ 0.5°) REFRACTED THROUGH ACRYLIC RESIN (PLEXIGLAS)

STEEL	90°	80°	75°	70°	60°	45°
ALUMINUM	75°	72°	69°	65°	57°	43°
MAGNESIUM	70°	68°	65°	62°	54°	42°
TITANIUM	74°	72°	68°	65°	56°	43°

PLEXIGLAS	$C_L$	2730 meter per second	(+ 30')
STEEL	$C_t$	3240 meter per second	
ALUMINUM	$C_t$	3130 meter per second	
MAGNESIUM	$C_t$	3050 meter per second	
TITANIUM	$C_t$	3120 meter per second	

$$\frac{\sin \alpha}{\sin \beta} = \frac{C_L \text{ Plexiglas}}{C_t}$$

EXAMPLE: Angle transducer marked 70° Fe. will give a refracted angle in aluminum and titanium of 65°; in magnesium of 62°.

$$\text{thus: } \frac{\sin \alpha^\circ}{\sin 70^\circ} = \frac{2730}{3240} \quad \therefore \sin \alpha^\circ = 0.792; \alpha = 52.4^\circ$$

$$\frac{0.792}{\sin \beta_{Al}^\circ} = \frac{2730}{3130} \quad \therefore \sin \beta_{Al}^\circ = 0.908; \beta_{Al} = 65.0^\circ$$

$$\frac{0.792}{\sin \beta_{Mg}^\circ} = \frac{2730}{3050} \quad \therefore \sin \beta_{Mg}^\circ = 0.884; \beta_{Mg} = 62.0^\circ$$

Figure E-4. Angles of Refraction for Various Materials

**BOLD FACE FIGURES Wall Thickness in Inches**  
**LIGHT FACE FIGURES Wt. per Ft. in pounds**

PIPE SIZE	O. D. in inches	5	10	20	30	40	STD.	60	80	E.H.	100	120	140	160	DBLE. E.H.
¼	.405	.035	.049			.068	.068		0.95	.095					
		.1383	.1863			.2447	.2447		.3145	.3145					
½	.540	.049	.065			.088	.088		.119	.119					
		.2570	.3297			.4248	.4248		.5351	.5351					
¾	.675	.049	.065			.091	.091		.126	.126					
		.3276	.4235			.5676	.5676		.7388	.7388					
¾	.840	.065	.083			.109	.109		.147	.147				.187	.294
		.5383	.6710			.8510	.8510		1.088	1.088				1.304	1.714
¾	1.050	.065	.083			.113	.113		.154	.154				.218	.308
		.6838	.8572			1.131	1.131		1.474	1.474				1.937	2.441
1	1.315	.065	.109			.133	.133		.179	.179				.250	.358
		.8678	1.404			1.679	1.679		2.172	2.172				2.844	3.659
1¼	1.660	.065	.109			.140	.140		.191	.191				.250	.382
		1.107	1.806			2.273	2.273		2.997	2.997				3.765	5.214
1½	1.900	.065	.109			.145	.145		.200	.200				.281	.400
		1.274	2.085			2.718	2.718		3.631	3.631				4.859	6.408
2	2.375	.065	.109			.154	.154		.218	.218				.343	.436
		1.604	2.638			3.653	3.653		5.022	5.022				7.444	9.029
2½	2.875	.083	.120			.203	.203		.276	.276				.375	.552
		2.475	3.531			5.793	5.793		7.661	7.661				10.01	13.70
3	3.5	.083	.120			.216	.216		.300	.300				.437	.600
		3.029	4.332			7.576	7.576		10.25	10.25				14.32	18.58
3½	4.0	.083	.120			.226	.226		.318	.318				.437	.636
		3.472	4.973			9.109	9.109		12.51	12.51					22.85
4	4.5	.083	.120			.237	.237	.281	.337	.337		.437		.531	.674
		3.915	5.613			10.79	10.79	12.66	14.98	14.98		19.01		22.51	27.54
4½	5.0						.247			.355					.710
							12.53			17.61					32.53
5	5.563	.109	.134			.258	.258		.375	.375		.500		.625	.750
		6.349	7.770			14.62	14.62		20.78	20.78		27.04		32.96	38.55
6	6.625	.109	.134			.280	.280		.432	.432		.562		.718	.864
		7.585	9.289			18.97	18.97		28.57	28.57		36.39		45.30	53.16
7	7.625						.301			.500					.875
							23.57			38.05					63.08
8	8.625	.109	.148	.250	.277	.322	.322	.406	.500	.500	.593	.718	.812	.906	.875
		9.914	13.40	22.36	24.70	28.55	28.55	35.64	43.39	43.39	50.87	60.93	67.76	74.69	72.42
9	9.625						.342			.500					
							33.90			48.72					
10	10.75	.134	.165	.250	.307	.365	.365	.500	.593	.500	.718	.843	1.000	1.125	
		15.19	18.70	28.04	34.24	40.48	40.48	54.74	64.33	54.74	76.93	89.20	104.1	115.7	
11	11.75						.375			.500					
							45.55			60.07					
12	12.75	.165	.180	.250	.330	.406	.375	.562	.687	.500	.843	1.000	1.125	1.312	
		22.18	24.20	33.38	43.77	53.53	49.56	73.16	88.51	65.42	107.2	125.5	139.7	160.3	
14	14.0		.250	.312	.375	.437	.375	.593	.750	.500	.937	1.093	1.250	1.406	
			36.71	45.68	54.57	63.37	54.57	84.91	106.1	72.09	130.7	150.7	170.2	189.1	
16	16.0		.250	.312	.375	.500	.375	.656	.843	.500	1.031	1.218	1.437	1.593	
			42.05	52.36	62.58	82.77	62.58	107.5	136.5	82.77	164.8	192.3	223.5	245.1	
18	18.0		.250	.312	.437	.562	.375	.750	.937	.500	1.156	1.375	1.562	1.781	
			47.39	59.03	82.06	104.8	70.59	138.2	170.8	93.45	208.0	244.1	274.2	308.5	
20	20.0		.250	.375	.500	.593	.375	.812	1.031	.500	1.280	1.500	1.750	1.968	
			52.73	78.60	104.1	122.9	78.60	166.4	208.9	104.1	256.1	296.4	341.1	379.0	
24	24.0		.250	.375	.562	.687	.375	.968	1.218	.500	1.531	1.812	2.062	2.343	
			63.41	94.62	140.8	171.2	94.62	238.1	296.4	125.5	367.4	429.4	483.1	541.9	

Figure E-5. A. S. A. Pipe Schedules

TYPE	CURRENT MIL-T SPEC	CONDITION	PRINCIPAL APPLICATION	INSPECTION FREQ.
304	MIL-T-8504 (ASG(2) (S OR W))	ANNEALED	HIGH PRESSURE (3000 PSI), HYDRAULIC AND PNEUMATIC SYSTEMS.	5MC
	MIL-T-8506(1) (S)	ANNEALED	LOW PRESSURE FUEL LINES, NOT RECOMMENDED FOR WELDING, NOT PRESSURE TESTED.	5MC
	MIL-T-8506(1) (W)	ANNEALED	LOW PRESSURE FUEL LINES, NOT RECOMMENDED FOR WELDING.	5MC
	MIL-T-6845(S) (S OR W)	1/8 HARD	HIGH PRESSURE (3000 PSI), HYDRAULIC AND PNEUMATIC SYSTEMS.	5MC
	MIL-T-5695(B) ASG (S OR W)	1/4 HARD	HIGH CORROSION RESISTANT A.Q. STRUCTURAL TUBING. NOT PRESSURE TESTED. NOT RECOMMENDED FOR FLARING OR SEVERE BENDING.	
	MIL-T-5695(B) ASG (S OR W)	1/2 HARD		
321	MIL-T-8606A (ASG) (S)	ANNEALED	HIGH CORROSION RESISTANT A.Q. STRUCTURAL TUBING. NOT PRESSURE TESTED. RECOMMENDED FOR WELDING.	
	MIL-T-8606A (ASG) (W)	ANNEALED	HIGH CORROSION RESISTANT A.Q. TUBING. RECOMMENDED FOR WELDING.	
	MIL-T-8808A (S OR W)	ANNEALED	HYDRAULIC AND PNEUMATIC SYSTEMS, PRESSURE TESTED. RECOMMENDED FOR WELDING.	
	MIL-T-6737A (2) (W)	ANNEALED	STRUCTURAL APPLICATIONS WHERE INSIDE FLASH IS ALLOWED. NOT PRESSURE TESTED.	
347	MIL-T-8606A (ASG) (S)	ANNEALED	HIGH CORROSION RESISTANT A.Q. STRUCTURAL TUBING. NOT PRESSURE TESTED. RECOMMENDED FOR WELDING.	2.25 - 5 MC
	MIL-T-8606A (ASG) (W)	ANNEALED	HIGH CORROSION RESISTANT A.Q. TUBING. RECOMMENDED FOR WELDING.	
	MIL-T-8808A (S OR W)	ANNEALED	HYDRAULIC AND PNEUMATIC SYSTEMS, PRESSURE TESTED. RECOMMENDED FOR WELDING.	
	MIL-T-6737A (2) (W)	ANNEALED	STRUCTURAL APPLICATIONS WHERE INSIDE FLASH ALLOWED. NOT PRESSURE TESTED.	
316		ANNEALED	PARTS REQUIRING CORROSION AND HEAT RESISTANCE UP TO 1600°F.	
410		ANNEALED	OIL LINES AND AIR PASSAGES REQUIRING RESISTANCE TO OXIDATION UP TO 1000°F.	
4130 ASG	MIL-T-6736 ASG (3)	NORMALIZED	AIRCRAFT FOR WELDED AND OTHER CONSTRUCTIONS.	5 MC
4130 ASG	MIL-T-6736 ASG (3)	HEAT TREATED	AIRCRAFT FOR WELDED AND OTHER CONSTRUCTIONS.	
4130 ASG	MIL-T-6736 ASG (3)	HEAT TREATED	AIRCRAFT FOR WELDED AND OTHER CONSTRUCTIONS.	
4130		ANNEALED	AIRCRAFT QUALITY, HEAVY WALL FOR MACHINING.	
4130 (W)	MIL-T-6731 (1)	ANN., NORM. OR H.T.	AIRCRAFT CONSTRUCTION.	
4135	MIL-T-6735 (1)	NORMALIZED	AIRCRAFT CONSTRUCTION. NOT RECOMMENDED FOR WELDING.	
4135	MIL-T-6735 (1)	HEAT TREATED	AIRCRAFT CONSTRUCTION. NOT RECOMMENDED FOR WELDING.	
4135	MIL-T-6735 (1)	HEAT TREATED	AIRCRAFT CONSTRUCTION. NOT RECOMMENDED FOR WELDING.	
4135		ANNEALED	A.Q. HEAVY WALL TUBING FOR MACHINING.	
4140		ANNEALED	A.Q. HEAVY WALL TUBING FOR MACHINING.	5 MC
4337		ANNEALED	A.Q. HEAVY WALL TUBING FOR MACHINING.	
4340		ANNEALED	A.Q. IN MACHINABLE CONDITION.	
8740		ANNEALED	A.Q. HEAVY WALL TUBING FOR MACHINING.	
1010	NONE	ANNEALED	OIL LINES, FLEXIBLE AND WELDABLE ASSEMBLIES.	
1015	NONE	MACHINABLE	LOW STRENGTH STRUCTURAL TUBING.	
1025 (S)	MIL-T-5066A (S)	STRESS-RELIEVED	AIRCRAFT ASSEMBLIES WHERE STRENGTH IS NOT ESSENTIAL.	
1025 (W)	MIL-T-5066A (W)	AS WELDED, NORMALIZED OR STRESS-RELIEVED	AIRCRAFT ASSEMBLIES WHERE STRENGTH IS NOT ESSENTIAL.	

Figure E-6. Steel Tube Specifications



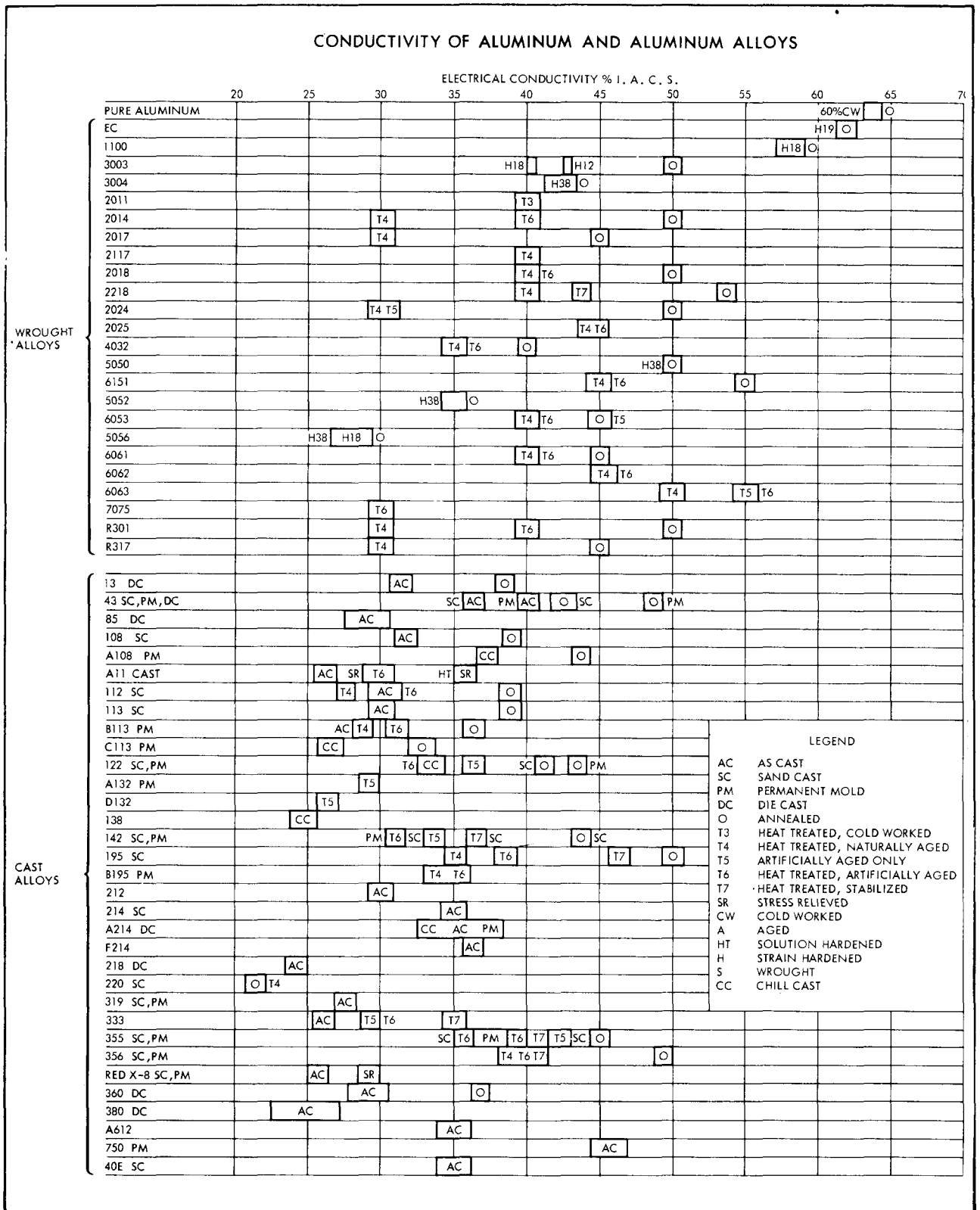


Figure E-7. Electrical Conductivities for Non-Magnetic Materials (Sheet 1 of 3)

## CONDUCTIVITY OF MAGNESIUM AND MAGNESIUM ALLOYS

ELECTRICAL CONDUCTIVITY % I. A. C. S.

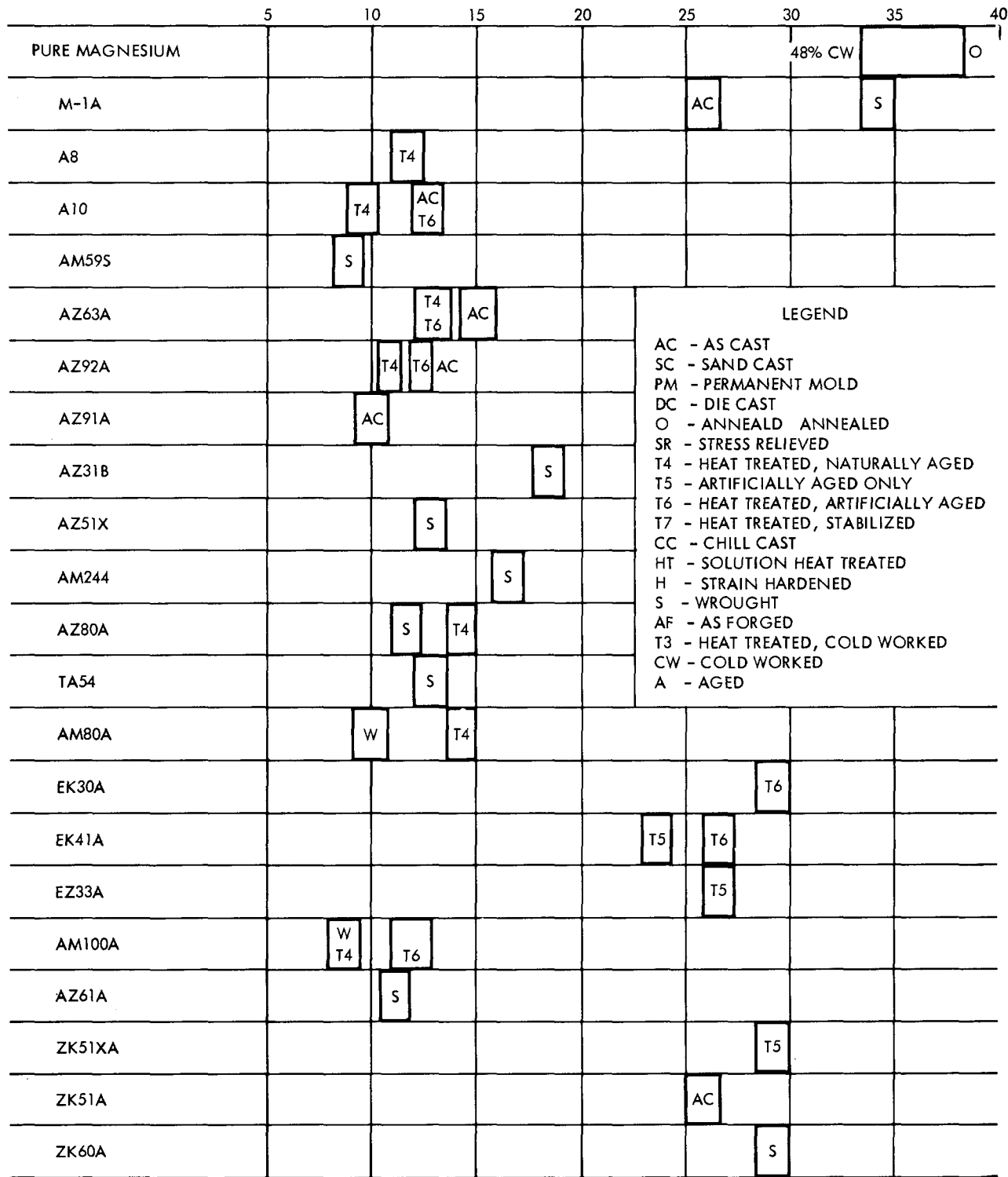


Figure E-7. Electrical Conductivities for Non-Magnetic Materials (Sheet 2 of 3)

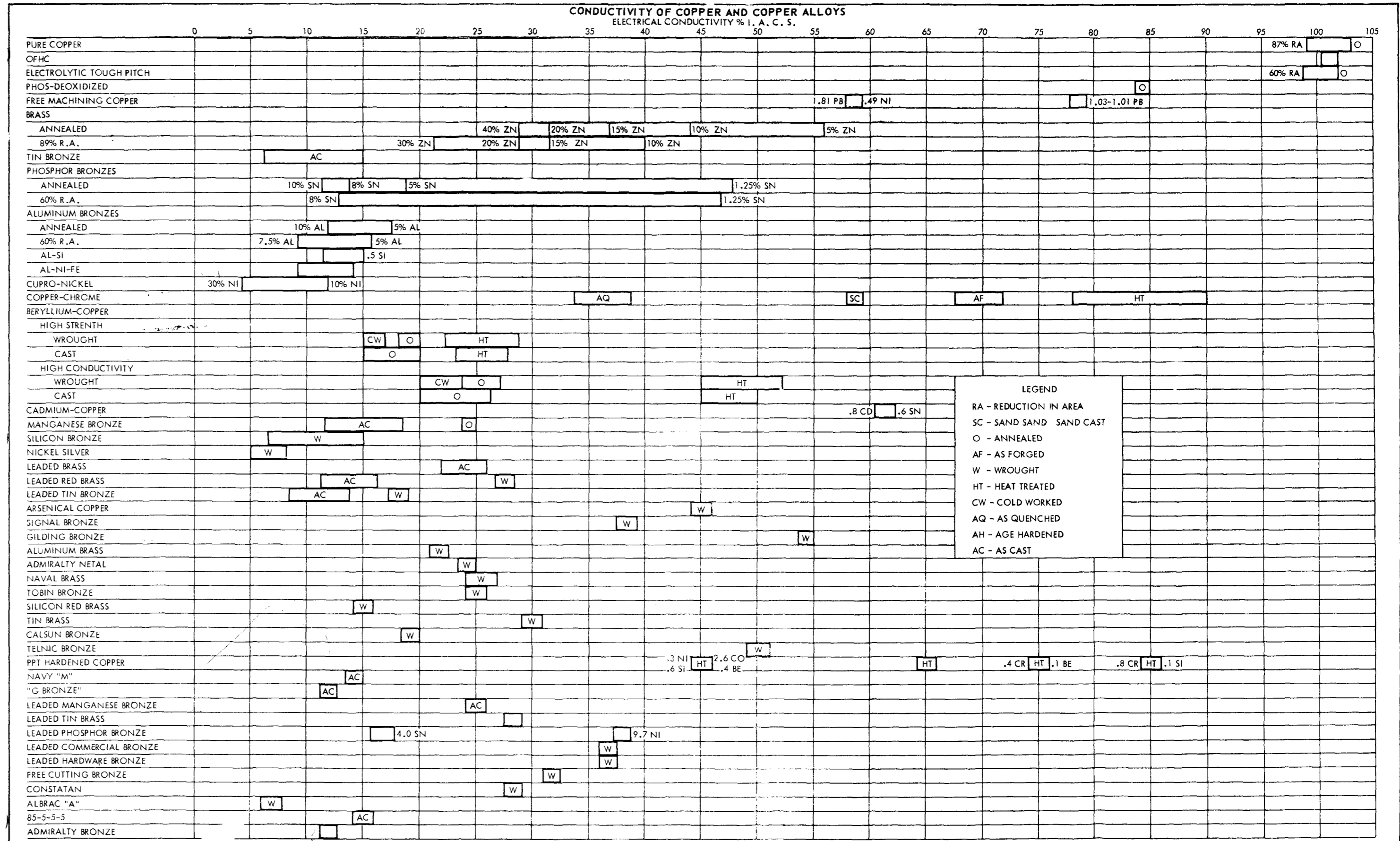


Figure E-7. Electrical Conductivities For Non-Magnetic Materials (Sheet 3 of 3)



	QUARTZ (SiO <sub>2</sub> )	LITHIUM SULPHATE (LiSO <sub>4</sub> )	BARIUM TITANATE (BaTiO <sub>3</sub> )	LEAD METANIOPATE (PbNb <sub>2</sub> O <sub>6</sub> )	LEAD ZIRCONATE - TITANATE (PbZrO <sub>3</sub> PbTiO <sub>3</sub> (APPROX.))	
DENSITY	2.65	2.06	5.7	5.8	7.6	10 <sup>3</sup> KG/M <sup>3</sup>
CHARACTERISTIC ACOUSTIC IMPEDANCE Z	15.3	11.2	34	16	22.8	10 <sup>6</sup> KG/M <sup>2</sup> S
RESONANCE FREQUENCY AT 1 MM	2.9	2.4	2.2	1.4	1.9	KC/S MM
DIELECTRIC CONSTANT	4.5	10.3	1700	225	1200	
QUALITY FACTOR	10 <sup>6</sup>	-	400	11	500	
ELECTROMECHANICAL COUPLING FACTOR FOR THICKNESS MADE	.1	.35	.52	.42	.76	
ELECTROMECHANICAL COUPLING FACTOR FOR RADIAL MODE (DISTURBING INFLUENCE)	.1	-	.35	.07	.30	
PIEZOELECTRIC MODULUS FOR THICKNESS MODE d	2.3	15.5	190	80	190	10 <sup>-12</sup> M/V
PIEZOELECTRIC DEFORMATION CONSTANT FOR THICKNESS MODE h	4.9	8.2	1.1	1.1	-	10 <sup>9</sup> V/M
PIEZOELECTRIC PRESSURE CONSTANT G	57	70	12	37	28	10 <sup>-3</sup> V/M NM <sup>2</sup>
CURIE TEMPERATURE	575	75	150	550	320	DEGREES CENTIGRADE
OPERATING TEMPERATURE (MAX)	500	60	100	500	250	DEGREES CENTIGRADE
E MODULUS	8.	-	11	-	6.8	10 <sup>-11</sup> N/M <sup>2</sup>

LEGEND:

- KG = Kilograms
- M = Meters
- KC = Kilocycles
- S = Seconds
- V = Volt
- N = Newton

Figure E-8. Data Covering Piezoelectric and Electrostrictive Materials

<u>NAME</u>	<u>CAPITAL</u>	<u>LOWER CASE</u>	<u>DESIGNATION</u>
Alpha	A	$\alpha$	Angles
Beta	B	$\beta$	Angles-Flux density
Gamma	$\Gamma$	$\gamma$	Specific Gravity
Delta	$\Delta$	$\delta$	Variations-density
Theta	$\theta$	$\theta$	Phase angle
Lambda	$\Lambda$	$\lambda$	Wavelength
Mu	M	$\mu$	Micro, permeability, Amplification factor
Pi	$\Pi$	$\pi$	Ratio of Circumference to diameter (3.1416)
Rho	P	$\rho$	Resistivity - conductivity
Sigma	$\Sigma$	$\sigma$	Summation
Phi	$\Phi$	$\phi$	Magnetic flux
Omega	$\Omega$	$\omega$	Capital: Ohms Lower Case: Angular velocity

Figure E-9. Greek Symbols

ANGLE	SIN.	COS.	TAN.	COT.
35	0.574	0.819	0.700	1.428
45	0.707	0.707	1.000	1.000
50	0.766	0.643	1.192	0.839
60	0.866	0.500	1.732	0.577
70	0.940	0.342	2.747	0.364
75	0.966	0.259	3.732	0.268
80	0.985	0.174	5.671	0.176

For calculation of secants or cosecants the following formulas are used:

$$\sec = \frac{1}{\sin.}$$

$$\csc = \frac{1}{\cos}$$

Figure E-10. Trigonometrical Functions

<u>DIAMETER</u>	<u>AREA</u>
	$\frac{\pi D^2}{4}$
<u>IN.</u>	<u>SQ. IN.</u>
.25	.049
.50	.196
.75	.442
1.00	.785
1.25	1.135
1.50	1.767
1.75	2.377
2.00	3.142

Figure E-11. Conversion Factors

<u>MULTIPLY</u>	<u>BY</u>	<u>TO OBTAIN</u>
Centimeters	$3.281 \times 10^{-2}$	Feet
Centimeters	0.3937	Inches
Centimeters	0.01	Meters
Centimeters	10	Millimeters
Centimeters	393.7	Mils
Centimeters	$1.094 \times 10^{-2}$	Yards
Inches	$8.333 \times 10^{-2}$	Feet
Inches	$10^3$	Mils
Inches	2.540	Centimeters
Inches	$2.778 \times 10^{-2}$	Yards
Meters	100	Centimeters
Meters	3.281	Feet
Meters	39.37	Inches
Meters	$10^{-3}$	Kilometers
Meters	$10^3$	Millimeters
Meters	1.094	Yards

Figure E-12. Conversion Factors

<u>NUMBER</u>	<u>CONDITIONS</u>	<u>C<sub>L</sub></u> <u>(METERS/SECONDS)</u>	<u>C<sub>t</sub></u>
1015	Annealed	5940	3240
1045	Annealed	5940	3240
1095	Annealed	5935	3238
4130	Annealed	5950	3265
4130	Hardened	5910	3235
4130	Normalized	5930	3240
4135	Normalized	5900	3210
4320	Annealed	5930	3220
52100	Annealed	6000	3275
52100	Hardened	5900	3210
430	Annealed	6020	3365
304	Annealed	5950	3265
347	Annealed	5950	3265
Mo. High Speed Tool Steel	Annealed	6000	3275
Mo. High Speed Tool Steel	Hardened	5890	3200
High C. High Cr. Coldworked Steel	Annealed	6130	3300
High C. High Cr. Coldworked Steel	Hardened	6000	3215
Steel (Average)		5952	3249
*Steel Values Used with IIW Block		6000	3300

\*Average steel values used in IIW Block for conversion of longitudinal to transverse wave characteristics (paragraph 4-61) when calibrating the equipment to a sound path 3.64" long for longitudinal waves, that is equivalent to a sound path 2.0" long for transverse or shear waves.

THUS:  $\frac{6000}{3300} \times 20 = 3.64''$

Figure E-13. Sound Velocities in Steel

c	Centi
d	Deci
dk	Deka
h	Hecto
K	Kilo
M	Mega
$\mu$	Micro
m	Milli

Figure E-14. Abbreviations for Metric Prefixes

ac	Alternating Current
amp	Ampere
cm	Centimeter
cps	Cycles per second
db	Decibel
dc	Direct Current
ft	Feet
f	Frequency
in	Inch
kc	Kilo-cycle
k $\Omega$	Kilo-Ohm
kw	Kilo-watt
Mc	Megacycle
M $\Omega$	Megohm
$\mu$ a	Micro-ampere
$\mu$ F	Micro-farad
$\mu$ V	Micro-volt
$\mu$ V/meter	Micro-volt per meter
ma	Milli-ampere
mh	Milli-henry
mv	Milli-volt
mv/meter	Milli-volt per meter
mw	Milli-watt
$\Omega$	Ohm
r-f	Radio Frequency

Figure E-15. Abbreviations and Letter Symbols



## APPENDIX VI GLOSSARY

- A-SCAN.** A data presentation method by which intelligence signals from a single object location are displayed. As generally applied to pulse echo ultrasonics, the horizontal and vertical sweeps are proportional to time or distance and amplitude or magnitude respectively. Thus the location and magnitude of acoustical interface are indicated as to depth below the transducer.
- ABSORPTION.** The loss of energy caused by small discontinuities in the materials. The sound energy is dispersed at the boundaries of the discontinuities.
- ACCOUSTICAL IMPEDANCE.** The factor which determines reflection at a boundary (interface). It is the product of the material density and the sound velocity within the material. Indicated with Z. Also named "Sound resistance."
- ADIABATICAL DIVERGENCE.** Irregularities in divergence due to changes in molecular activity in a material caused by the temperature of the material.
- AGGREGATE CONDITION.** There are three aggregate conditions namely; gaseous, liquid and solid. As long as a material remains in its "aggregate condition" the sound velocity will increase with temperature.
- ALTERNATING CURRENT.** A periodic conduction current that reverses direction at regular intervals.
- ALTERNATING FIELD.** Region or space transversed by force of alternating current.
- AMPLIFIER.** A device which increases the magnitude of an incoming signal.
- AMPLITUDE.** Referring to the vertical deflection of the oscillogram. The vertical height of the indication measured from the lowest to the highest point of the oscillogram.
- ANGLE OF INCIDENCE.** The angle between the original direction of the ultrasonic beam and an imaginary line drawn perpendicular to the reflecting surface.
- ANGLE OF REFLECTION.** The angle between the reflected ultrasonic beam and an imaginary line drawn perpendicular to the reflecting surface.
- ANGLE OF REFRACTION.** The angle formed between the ultrasonic beam as it enters a medium of different acoustical properties and a line drawn perpendicular to the boundary between the two media.
- ANGLE TRANSDUCER.** A transducer in which the sound beam is set to a predetermined angle to generate longitudinal transverse or surface waves in the part under inspection.
- ANISOTROPIC.** Having properties, as conductivity, velocity of sound, light, etc., which vary according to the direction in which they are measured.
- ANTINODE.** The point halfway between two adjacent nodes in a vibrating body.
- ASYMMETRICAL.** (See symmetrical) not symmetrical.
- ATTENUATION.** The dissipation in an ultrasonic system due primarily to the viscosity or damping of the medium. Heat conduction and radiation between the compression and rarification section of the waves also has a major part in the losses experienced.
- B-SCAN.** A data presentation method generally applied to pulse echo techniques which yields a two dimensional view of a cross-sectional plane through the part under inspection.
- BACK REFLECTION.** Indication on the cathode ray tube display representing the opposite side of the specimen under test.
- BACKGROUND NOISE.** Noise due to disturbances of periodic or random occurrence.
- BACK REFLECTION, LOSS OF.** See Loss of Back Reflection.
- BARIUM TITANATE.** Polycrystalline Barium Titanate  $BaTiO_3$ . A ceramic material composed of many individual crystals fired together and polarized by the application of an electrostatic field.
- BEAM.** A directed flow of energy into space or matter.
- BLOCKS, REFERENCE (or Calibration).** Blocks used to calibrate ultrasonic pulse echo equipment in direct relationship to the CRT display. Used to adjust for linearity, sound velocity, as reference for sensitivity and to control quality of performance of the instrument and transducer characteristics.
- See IIW. Reference Block.

- BLOCKS, TEST.** A block or series of blocks of material containing artificial or actual discontinuities of one or more reflecting areas at one or more distances from the test surface, which are used for reference in defining the size and distance of defective areas in materials.
- BONDARY.** The interface between two media.
- BOUNDARY REFLECTION.** Reflection at the interface of two media.
- BURN THROUGH.** A melting of metal away from the root of the weld or through the backing strip. This discontinuity appears on a radiograph as individual or continuous darkened areas of elongated or rounded contours that may be surrounded by light rings.
- C-SCAN.** A data presentation method giving a two dimensional plan view of the scanned surface of the part (shadows, reflections).
- CALIBRATION.** Process of comparing an instrument or device with a reference standard.
- CATHODE-RAY-TUBE.** An electron tube in which a beam of electrons is used to produce an image on a fluorescent screen at the face of the tube.
- COLLIMATING NOZZLE.** Plexiglas tube of special shape, which is fixed to an immersed scanning transducer to decrease the diameter of the sound-beam.
- COLLIMATION.** Decreasing the diameter of the sound-beam.
- COMPENSATOR.** An electric device by which the impedance in part of a network is changed. The current increment which is thereby produced at any point in the network is equal to the current that would be produced at that point by a compensating e.m.f.
- COMPRESSIONAL WAVE.** Waves in which the particle motion or vibration is in the same direction as the propagated wave. Same as longitudinal wave. Longitudinal wave preferred expression.
- CONTACT SCANNING.** Testing with transducer in direct contact with material through a layer of couplant.
- COUPLANT.** Any media used between the face of the transducer and surface of the material under inspection to permit transmission of ultrasonic energy.
- CRATER CRACK.** A crack originating in the crater in a weld bead. This discontinuity appears radiographically as short fine lines extending outward from the crater.
- CRYSTAL MOSAICS.** Two or more crystals mounted in the same plane in one holder and connected so as to cause all crystals to vibrate as one unit.
- CRYSTALS, X-CUT.** Section cut so that its parallel planes are perpendicular to the X-axis of the crystal. A thickness longitudinal mode of vibration occurs when electrically excited.
- CRYSTALS, Y-CUT.** Section cut so that its parallel planes are perpendicular to the Y-axis of the crystal. A thickness transverse mode of vibration occurs when electrically excited.
- CRYSTALS, Z-CUT.** Section cut so that its thickness parallel planes are perpendicular to the Z-axis of the crystal.
- DAMPING.** Decrease or decay of ultrasonic wave amplitude with respect to time.
- DEAD ZONE.** The extent of an area directly under the transducer where no defects can be detected due to the width of the transmitting pulse.
- DEFECT REFLECTION.** The indication of the return of reflected energy from flaws in the material.
- DELAYED SWEEP.** Magnification of portions of the time scale obtained on the cathode-ray tube screen, so that any portion of the total distance being tested can be presented on the viewing screen.
- Example: When testing an 18-foot bar, the unit can be so adjusted that the length from the fifth to the sixth foot of the bar can be presented across the entire width of the viewing screen. Both the initial pulse and the back reflection will be off screen in this case.
- DENSITY.** The ratio of the mass of an object to its volume. Indicated with Greek Symbol ( $\Delta$  - lower case).
- DIFRACTION.** The bending of a wave front around an obstacle.
- DIFFUSE REFLECTION.** Rough surface reflections of ultrasonic waves from irregularities of the same order of magnitude or greater than the wave length.

**DISCONTINUITY.** A general term applied to all conditions which present an obstacle to the passage of the ultrasonic beam during test.

**DIVERGENCE.** Natural spreading of the sound beam.

**DOMAIN MOBILITY.** Domain is a substructure in a ferro-magnetic material within which all the elementary magnetics (electron spins) are held aligned in one direction by inner atomic force, if isolated it makes a permanent magnetic. Mobility is the latitude available before disturbing the electron spin.

**DOUBLE SEARCHING TEST UNIT.** A test method employing two separate searching units, one for sending and the other for receiving or both receiving and transmitting. The first through-transmission, the second reflection technique.

**ECHO.** See reflection. Reflection preferred word. Only used to indicate the basic type of equipment or method; pulse-echo ultrasonics.

**EDDY CURRENT.** Currents generated in a material due to variations in an applied magnetic field.

**EFFECTIVE DEPTH OF PENETRATION.** - Eddy current.

$$\frac{1}{\sqrt{\mu \cdot \sigma \cdot f}} \quad \text{Where } \begin{array}{l} \mu = \text{permeability} \\ \sigma = \text{conductivity in \%} \\ \text{I.A.C.S.} \\ f = \text{frequency in K.C.} \end{array}$$

**EFFECTIVE PENETRATION** - Ultrasonic maximum depth at which a defect can be detected by ultrasonic testing. The effective penetration will vary widely with different types of materials, size of crystal, size of defect and frequency used.

**ELASTIC LIMIT.** The highest unit stress to which a material may be subjected without causing a permanent deformation to remain, upon release of the stress.

**ELASTICITY.** The ability of a material to absorb and transmit energy without suffering a permanent change in shape. This change may be large or microscopically small, and will occur when energy is applied to the material, but once the disturbance is removed, the material will revert to its original shape.

**ELECTRON SPIN.** Elementary magnets in the domain of ferro-magnetic material or the spinning of an electron on its axis.

**ELECTROSTRICTIVE.** The ability of sintered ceramic materials to undergo a dimensional change when an alternating current is applied to it and visa versa.

**EMULSIFICATION.** Mixing two otherwise incompatible substances, usually liquids such as oil and water, by using a third substance (emulsifier) as a catalyst.

**END SUPPRESSION.** To eliminate a spurious electronic signal caused when the last part of a tube passes through a solenoid.

**EXPANDED SWEEP.** An expansion of the horizontal sweep line or time axis on the viewing screen of the ultrasonic instrument. This permits close scrutiny of any portion of the pattern when used in conjunction with the sweep delay. See range magnification or delayed sweep.

**EXTRUDED.** Having been shaped or formed by forcing through dies by pressure, usually with the application of heat.

**FAR ZONE.** Divergence of sound beam beyond the near zone.

**FATIGUE CRACK.** A crack which enlarges under repeated cycles of stress; a progressive fracture.

**FLUORESCENT SCREEN.** The coating of material in the cathode-ray tube which glows under electronic bombardment from the cathode.

**FOCUSING.** Concentration or convergency of energy into a small beam.

**FREQUENCY.** The frequency of a wave motion is the number of complete waves which pass a given point per second. The medium makes one vibration for each wave that passes; hence the frequency of a wave motion has precisely the same significance of a periodic motion.

**FRESNELL ZONE.** See Near Zone.

**GAS POROSITY.** This term is used to describe gas inclusions which occur in the weld as cavities. They are formed by gases that fail to escape as the weld metal cools. On a radiograph these cavities appear as round or elongated spots of varying sizes and densities. Porosity may occur singly, linearly, in clusters, or randomly scattered throughout the weld.

- GHOST.** Spurious indications on the CRT screen that could not be explained. This expression is without technical foundation and should not be used.
- HARMONICS.** Those vibrations differing in frequency from the fundamental vibration by an integral multiple.
- HASH.** Numerous small indications appearing on the viewing screen of the ultrasonic instrument indicative of many small inhomogeneities in the material or caused by grain structure or (electronic) background noise.
- HEIGHT OF INDICATIONS.** Amplitude of reflection displayed on the oscilloscope.
- HETEROGENEOUS.** A structure composed of unlike or unrelated elements.
- ICICLES (TEARDROPS).** A coalescence of metal beyond the root of the weld which appears as individual, light, circular indications on a radiograph.
- IMMERSION TESTING.** A method of testing in which the part to be tested is immersed in water or other liquid, so that it works as a couplant. The ultrasonic transducer is also immersed but is not in contact with the part. Immersion testing is most useful in mass inspection of parts with regular or symmetrical shapes.
- INCOMPLETE PENETRATION.** This discontinuity always occurs at the root of a welded joint and is caused by the absence of full penetration to the deepest portion of the weld joint. This discontinuity appears, on a radiograph, as a straight dark line along the center of the weld and depending upon the width of the discontinuity will vary from a thin, sharp, discontinuous line to a broad, diffused, continuous one.
- INCLUSIONS.** Slag, particles of impurities, usually oxide, sulphide, silicates and such, which are mechanically held during solidification or which are formed by subsequent reaction of the solid metal.
- INDEX OF REFRACTION.** The ratio between wave speed in one material and wave speed in a second material.
- INDICATION.** A reflection of vertical signal centered on the base line of the screen caused by an indication of reflection from the material under test.
- INERTIA.** The property which causes bodies at rest to remain at rest unless acted upon by some external force, and which causes bodies moving at a constant velocity to continue at this uniform rate and in the same direction, unless acted upon by an external force which changes the velocity or direction.
- INGOTS.** A mold in which metal is cast. A mass of metal cast into a shape, to be remelted later for casting or finished by rolling, forging, etc.
- INITIAL PULSE INDICATION.** See transmitting pulse.
- INTERFACE.** A boundary between two materials of different acoustical impedance.
- ISOTROPIC.** Having the same properties in every direction.
- KILOCYCLE.** One thousand cycles.
- LACK OF FUSION.** Failure of weld metal to fuse completely with the base metal or with the preceding beads. Its appearance radiographically, is that of a dark indication usually of elongated shape.
- LAMB WAVE.** A group of modes of ultrasonic vibrations capable of propagation in materials. Propagation occurring over the surface of a solid whose thickness is comparable to the wave length.
- LAMINATIONS.** Metal defects with separation or weakness generally aligned parallel to the work surface of the metal may be the result of pipe, blisters, seams, inclusions or segregation elongated and made directional by working.
- LAP.** A surface defect appearing as a seam caused from folding over hot metal fins, or sharp corners, and then rolling or forging, but not forming a homogeneous surface.
- LAW OF REFLECTION.** The law of reflection states that "The angle of reflection is equal to the angle of incidence."
- LONGITUDINAL WAVE.** Waves in which the particle velocity is restrained to motion in the direction of the wave propagation. Longitudinal waves are dilational and irrotational which means there is a change in the body volume. Longitudinal waves are also known as compression waves.

**LONGITUDINAL WAVE VELOCITY.** The rate of propagation of a wave parallel to the direction of motion of the particles.

**LONGITUDINAL WELD CRACK.** A rupture in the direction of the weld which appears on the radiograph as dark and usually well-defined irregular lines but in some instances as sharp straight lines. If the plane of the crack deviates from the direction of the X-ray beam, the crack will appear as a broad, poorly defined band; where the deviation is considerable, the crack may show up as a light shadowy area, difficult to detect.

**LOSS OF BACK REFLECTION.** The absence or decrease in amplitude of an indication of the far surface of the article being inspected.

**MAGNETOSTRICTION.** The expansion and contraction of a ferro-magnetic material under the influence of a changing magnetic field; sometimes used to generate ultrasonic waves of low frequency.

**MANIPULATOR.** A device used for orientation of the transducer assembly. As generally applied to immersion techniques, the device provides either an angular or normal (perpendicular) sound wave path at the point of application.

**MARKERS.** A series of square waves or other beam deflections that can be adjusted, displayed on the cathode-ray tube screen of the ultrasonic equipment used to determine the distance from the test surface of the article being inspected to a subsequent discontinuity or boundary.

**MASS.** A measure of the quantity of matter in a body as determined by comparing the changes in the velocities that result when the body and a standard body impinge. Mass is the quotient obtained by dividing the weight of a body by the acceleration due to gravity.

**MEDIA.** Plural for medium.

**MEDIUM.** That through or by which anything is accomplished.

**MEGACYCLE.** One million cycles.

**MEMBRANE.** Any thin, soft, pliable sheet or layer.

**METER.** A measure of length equal to 39.37 inches; the basis of the metric system.

**MILLIMETER.** One thousandth of a meter.

**MODE.** The term is used to describe particle motion in sound waves, as in "mode of vibration." The four common modes of vibration in ultrasonic testing are longitudinal, transverse, surface and lamb.

**MODULUS OF ELASTICITY.** A measure of rigidity of the metal. Ratio of stress within proportional limit to corresponding strain. Specifically the modulus obtained in tension or compression is YOUNG'S MODULUS, stretch modulus or modulus of extensibility.

**MOLECULES.** A unit of matter. The smallest particle of an element or compound that can exist in the free state and still retain the characteristics of the element or compound.

**MULTIPLE BACK REFLECTIONS.** Repetitive reflections from the far boundary of an article being inspected.

**NDT.** Abbreviation for non-destructive testing.

**NEAR ZONE EFFECTS.** Poor ultrasonic resolution arising from complex wave front characteristics. Also known as the Fresnel field.

**NEAR ZONE.** (Fresnel) In divergence of sound beam, the near zone is that zone which extends a limited distance from the transducer with the far zone beyond it. (See figure 4-14).

**NODE.** A point in a standing wave where some characteristic of the wave field has essentially zero amplitude.

**NOISE (electronic).** An unwanted disturbance within a useful frequency band.

**NON-DESTRUCTIVE TESTING.** A general term applied to all test methods which permit inspection or testing of a material or part without changing or damaging the material or part.

**ORIENTATION.** Angular position with respect to the test surface of the reflecting surface of the discontinuity.

**OSCILLOSCOPE.** An instrument for showing a visible pattern which is the graphical representation of electrical signals, by variations of the position of the focused spot or spots in accordance with these signals.

**PARTICLE MOTION.** Movement of particles in an article brought about by the action of a transducer.

- PATTERN.** The light picture traced on the viewing screen of the cathode-ray tube.
- PENETRATION.** Transmission of ultrasonic energy through an article. See Effective Penetration.
- PERIOD.** The period of a wave motion is the time required for a complete wave to pass a given point or the time required for one complete vibration of the medium. The period is the reciprocal of the frequency.
- PHASE.** A quantity indicating a particular stage of progress in any recurring operation such as a vibration. Phase is usually expressed as an angle or part of a cycle in which the complete cycle of operation equals 360 degrees.
- PIEZOELECTRIC.** The ability of certain crystals, to deform when an alternating current is applied to it and visa versa.
- PIEZOELECTRIC EFFECT.** The characteristic of a certain dielectric materials (quartz, Rochelle salts, etc.) to exhibit electrical charges on certain surfaces when the material is subjected to mechanical stress and conversely to exhibit mechanical vibrations when subjected to electrical charges.
- PIPE.** A cavity formed in metal, especially ingots, during the solidification of the last portion of liquid metal. Contraction of the metal caused this cavity.
- PLATED CRYSTAL.** Crystal on which metallic surfaces are deposited for protection or to give surfaces on which the electrical potential can be impressed.
- POTENTIAL.** Electric field intensity at a point resulting from the work necessary to bring a unit charge to a point from an infinite distance.
- PRESENTATION.** The method used to show ultrasonic wave information which may include A-, B- or C-scans displayed whether on various types of recorders or cathode-ray instrumentations.
- PROBE.** A transducer or search unit, generally used for a coil in eddy current inspection.
- PROPAGATION.** Propagation takes the form of a displacement of successive elements of the medium. If the substance is elastic, a restoring force tends to bring each element of material back to its original position. Since all such media possess inertia, the particle continues to move after it returns to the position from which it started, and finally reaches another different position past the original one. From the second point, it returns to its starting position, about which it continues to oscillate with constantly diminishing amplitude.
- PULSE.** Denotes same condition as wave train.
- PULSE ECHO.** The transmission of sound or other energy form into a material in the form of spaced pulses and recording the length of time necessary for each such pulse to travel through the material and return to the source of energy. All single searching unit (transducer) testing is based on the pulse-echo method.
- PULSE LENGTH.** Time duration of the pulse sent to the search unit.
- PULSE METHOD.** Contrary to a continuous method, the soundwave in the pulse method is interrupted at a low frequency (300-1000 c/s).
- PULSE RATE.** The number of pulses transmitted in a unit time. Also called pulse repetition rate. Abbreviation p.r.r.
- QUALIFYING AGENCY.** The agency, usually the employer, who qualifies personnel by issuing certifying papers classifying personnel as to Class I, Class II, Class III, and Class IV non-destructive testing inspectors.
- QUARTZ.** A form of silica occurring in hexagonal crystals or in crystalline masses. Silica is the most common of all solid minerals and may be colored, colorless, or transparent.
- RAREFACTION.** The thinning out, or moving apart of the particles in a material as an ultrasonic wave is propagated; opposite in its effect to compression. The sound wave is composed of alternate compressions and rarefactions of the material.
- RAY.** A ray is the path of one element of a wave front. In the case of unobstructed sound waves, the ray is always normal to a wave front. Thus, for plane waves, the rays are parallel lines normal to the wave fronts.
- RAYLEIGH WAVE.** A wave that travels on or close to the surface and readily follows the curvature of the part being examined. Reflections occur only at sharp changes of direction of the surface.
- RECTILINEAR PROPAGATION.** Rectilinear propagation is a characteristic exhibited by ultrasonic waves due to their short wave lengths. In such cases, the wave motion is transmitted in a straight line. Therefore, energy cannot travel around sharp discontinuities. It is this property which makes it possible to use ultrasonic waves for locating small defects, since any such small inhomogeneity will cast a sharp shadow behind it. As the wave length becomes shorter, the wave motion more closely approaches the ideal condition of absolute rectilinear propagation. However, the characteristic is pronounced enough to be evidenced by almost all testing frequencies.

- REFLECTED PULSE.** Any pulse or wave train which has changed its original direction of propagation as a result of striking a reflecting surface.
- REFLECTING SURFACE.** A boundary of a part under test which will cause a reflection of any wave train which strikes it. Any discontinuity of sufficient size also presents a reflecting surface to the wave train.
- REFLECTION.** The phenomenon by which a wave strikes a boundary and changes the direction of its propagation. Two important factors influence the reflection of an ultrasonic wave. One factor is the dimension and direction along the propagation path; the second factor is the cross-sectional area. The dimension along the propagation path interrupts the wave, but it is the cross-sectional area which determines the amount of reflection.
- REFRACTED RAY.** A refracted ray is one which has been changed both in velocity and direction as a result of its having crossed an interface between two different media and having initially been directed at an angle to that interface.
- REFRACTIVE INDEX.** The ratio of the velocity of a wave in one medium to the velocity of the wave in a second medium is the refractive index of the second medium with respect to the first. The refractive index is a measure of the amount a wave will be refracted when it enters the second medium after leaving the first medium.
- RESISTANCE.** The opposition offered by a substance or body to the passage through it of an electrical current; the reciprocal of conductance.
- RESONANCE.** The phenomenon shown by a vibrating system which responds with maximum amplitude under the action of a harmonic force which occurs when the frequency of the applied force is the same as a natural frequency of the vibrating body. Also the state of adjustment of a circuit permitting a maximum flow of current when an electromotive force of a particular frequency is impressed.
- RESONANCE METHOD.** A method employing the resonance principle for the measurement of dimensions and other frequency dependent qualities.
- RESONANT FREQUENCY.** The frequency at which a body will vibrate freely after being set in motion by some outside force.
- REVERSE PIEZOELECTRIC EFFECT.** Deformation of a crystal when an electric potential is applied to it.
- SAWTOOTH.** A wave form appearing on the screen of an oscilloscope that is similar in shape to teeth in a saw.
- SCANNING.** Moving the transducer along a test surface to obtain complete testing of the entire volume of a material being tested. Scanning may be either manual, where the unit is held and moved by hand, or scanning may be automatic where the transducer is held and moved with the aid of a mechanical device.
- SCATTERING.** Dispersion of ultrasonic waves in a medium due to causes other than damping.
- SCREEN.** The chemically-coated inside surface of the large end of a cathode-ray tube which becomes luminous when electron beams strike it.
- SEARCHING UNIT.** Also known as the transducer (preferred). The crystal-containing unit used as a transducer to convert electrical impulses into mechanical vibrations and to introduce such vibrations into the part being tested, and to also receive mechanical vibrations or reflections from the parts and convert them into electrical signals for display on the viewing screen.
- SEGREGATION.** Non-uniform distribution of alloying elements, impurities or microphases.
- SENSITIVITY.** Measure of the ability of the instruments to detect defects, based on the size of the defect detectable and value of indication obtained.
- SHADOW CONE.** The volume behind a discontinuity into which the ultrasonic vibrations do not enter due to their reflection by the discontinuity.
- SHEAR WAVES.** When the direction of a wave is perpendicular to the direction of vibration of the particles of the medium in which the wave travels, the wave is said to be a transverse or shear wave. The velocity of shear waves is approximately one half that of longitudinal waves.
- SIGNAL-TO-NOISE RATIO.** The ratio, expressed in terms of amplitude between the indication from the smallest defect desired to be detected, and the indications received from random reflections. In ultrasonic testing, any material which characteristically shows numerous random reflection indications, is said to be "noisy!"
- SINGLE TRANSDUCER.** A searching unit which both transmits and receives; used only in pulse-echo testing.
- SLAG INCLUSIONS.** Slag inclusions is the name given to non-metallic solid material which becomes entrapped in weld metal or between weld metal and base metal. They are primarily materials which are less opaque to X-rays and produce dark indications which are of elongated or irregular contour. They occur singly, in a linear distribution, or scattered randomly throughout the weld.

- SNELL'S LAW (SNELLIUS LAW).** The phenomenon wherein longitudinal waves are refracted and transformed into transverse or shear waves.
- SONAR.** An apparatus that detects the presence and location of submarines, underwater mines, etc., by means of inaudible high-frequency vibrations which are reflected back to it from the objects.
- SOUND.** A longitudinal or compression wave phenomenon which may be capable of exciting the auditory nerve.
- SOUND DISPERSION.** See Dispersion, Sound.
- SPECIFIC ACOUSTIC IMPEDANCE.** A factor which determines the amount of deflection which occurs at an interface and represents the product of the density of the medium in which the wave is propagating and the wave velocity.
- STACKED CRYSTAL.** Several crystals cemented together with the faces of the same polarity in the same direction.
- STANDING WAVE.** A type of wave in which there are nodes, or points of no motion, between which the medium vibrates. Stationary waves result when two similar waves travel simultaneously and in opposite direction through a medium as in a vibrating violin string.
- SURFACE WAVE.** See Rayleigh Wave.
- SWEEP.** The uniform and repeated movement of an electron beam across the fluorescent screen of a cathode-ray tube.
- SYMMETRICAL.** Similarity of form of arrangement on either side of a dividing line or plane.
- TEST FREQUENCY.** The frequency of vibration of the ultrasonic transducer employed for ultrasonic testing and the characteristic frequency of a part for eddy current testing.
- TEST SURFACE.** Any boundary of material under test on which the transducer is placed to transmit into the material or where a probe is placed to measure eddy current energy in the material.
- THROUGH TRANSMISSION.** A test method in which the vibrations emitted by one transducer that are aimed directly or indirectly, and received by, another transducer. The ratio between quantity of vibrations sent and received is a measure of the soundness or quality of material being tested.
- TIME BASE.** An indication on the horizontal trace of the cathode ray tube based on the frequency of the electrical input to the test instrument.
- TRACE.** The pattern or indication on the cathode-ray tube viewing screen.
- TRANSDUCER.** A transducer is a device by means of which energy may flow from one or more transmission systems to one or more other transmission systems. The energy transmitted by these systems may be of any form. For example, the energy may be electrical, mechanical, or acoustical.
- TRANSMISSION.** The act of introducing vibrations into the material to be tested.
- TRANSMISSION ANGLE.** The incident angle of the transmitted ultrasonic beam. The transmission angle is zero degrees when the ultrasonic beam is perpendicular to the test surface.
- TRANSMITTED PULSE.** The wave train introduced into the material being tested.
- TRANSVERSE WAVE.** Waves in which the vibration of the particles of the medium in which the wave is traveling is perpendicular to the direction of propagation. Such waves are due to shearing formations and are also known as shear waves.
- TRANSVERSE WELD CRACK.** In general their appearance is similar to longitudinal cracks except that they run transverse to the direction of the weld.
- TUNGSTEN INCLUSIONS.** Tungsten inclusions are associated with the tungsten inert-atmosphere welding methods. They may be in the form of small splinters, globules, or as pieces of the tungsten electrode. Radiographically, they appear as light indications with well-defined boundaries.
- ULTRASONIC GENERATOR.** A device capable of generating ultrasonic waves.
- ULTRASONIC TESTING.** A non-destructive method of testing materials by transmitting high frequency sound waves through the materials.
- ULTRASONIC VIBRATIONS.** Vibrational waves of a frequency above the normal hearing range. The term includes all waves greater than approximately 20,000 cycles per second.
- ULTRASONICS.** That branch of the science of physics which deals with the study of vibrational waves of a frequency range above the hearing range of the normal human ear. This includes all waves greater than approximately 20,000 cycles per second.



**ULTRASOUND.** Synonym for ultrasonic energy or vibrations.

**UNDERCUT.** A groove melted into the base metal adjacent to the toe of a weld and left unfilled by weld metal. Radiographically it appears as a dark linear indication of wavy contour occurring adjacent to the edge of the weld. This discontinuity may also be detected by visual examination of the weldment.

**VELOCITY.** Wave speed. Sound waves travel with velocity or speed, dependent upon the elasticity and the density of the medium in which they travel.

**VIBRATION.** Another name for wave.

**VISCOUS.** Liquid that is thick and resistant to flow.

**VOLUME.** Space occupied in cubic measurements.

**WAVE FRONT.** Continuous focus of the points in the medium which are in the same phase of their vibrations. For example, if the waves are emitted by a point source immersed in the medium, the wave fronts are concentric spheres. If the source is very distant, the radii of the spheres are very great, and the wave fronts become practically plane.

**WAVE LENGTH.** One wave length is the distance from a given point on a wave to the next corresponding point. The corresponding point is the point where the wave has the same amplitude and where displacement is in the same direction. The wave length of a periodic wave in an isotropic medium is the perpendicular distance between two wave fronts in which the displacements of a phase difference of one complete cycle.

**WAVE MOTION.** This is the propagation of deformations through a deformable or elastic medium.

**WAVE SPEED.** Sometimes called velocity. The velocity of a wave in moving from point to point. Speed will vary with temperature and with modulus of elasticity of the material in which it is traveling. Audible sound waves have a speed of approximately 1100 feet per second in air and almost 16,000 feet per second in steel. Wave speed equals frequency times the wave length,

**WAVE TRAIN.** A wave train is a short group of waves before or after which there are no waves.

**WAVES.** Waves are classified according to the nature of the forces concerned in them. Sound waves are a special kind of elastic wave. Sound waves occur in media which have two properties,

inertia and elasticity. If an element of media is displaced, it must be subject to a restoring force, tending to annul the displacement, and if the medium is to be capable of transmitting a train of waves, it must possess inertia so that when it is restored to its undisplaced position, the momentum which it has acquired may carry it through that position to a displacement opposite the original one. If the waves are of a constant type, that is, if the various characteristics of a particular wave are unchanged during its propagation, then the propagation is described by assuming that all the particles or elements of the medium execute identical orbits at the same time, each element being a little later than its neighbor nearer the source and a little earlier than its neighbor more remote from the source. This is to state then, that the phase of the vibrations varies continuously along the line of propagation. If a wave involves a physical displacement, the impression produced on an observer is that of a definite velocity. For example, the effect produced by securing a rope at one end and shaking the rope vertically at the other end.

**WAVES OF DILATION.** Dilation waves are those which change the volume of material in which they are propagated. Waves of dilation are also usually classified as irrotational. This latter term defines a condition in which there is no element of rotation of the particle.

**WAVES OF DISTORTION.** These waves which do not cause a change in the volume of the material in which they are propagated.

**WEDGE TESTING.** The use of a wedge between crystal and surface of test piece for testing of thin or irregular shaped pieces where it is not possible to direct waves in the desired direction using straight contact methods. The wedge directs the wave into the test piece at an angle, enabling the wave to reach surfaces otherwise inaccessible.

**WETTING AGENT.** A substance that promotes wetting. Wetting agents act by becoming absorbed on the surface to be wetted, so that it no longer repels the wetting liquid. Wetting agents are used in spreading liquids on surfaces. They are used in ultrasonics testing to increase the efficiency of a couplant.

**X-CUT CRYSTAL.** A crystal so cut that its major faces are parallel to Z and perpendicular to X; the electric field being applied in the X direction.

**Y-CRYSTAL.** A crystal cut perpendicularly to the Y-axis which vibrates transversely when an alternating current is applied to it.



## APPENDIX VII BIBLIOGRAPHY

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