SSC-253

A GUIDE FOR THE NONDESTRUCTIVE TESTING OF NON-BUTT WELDS IN COMMERCIAL SHIPS

PART ONE

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distribution is unlimited.

SHIP STRUCTURE COMMITTEE

1976

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SR-219

1 3 JAN 1976

Most of the information on nondestructive tests (NDT) of welded steel joints given in specifications, handbooks, and guides are for butt weld joints. However, there have and will be times when other weld joint configurations are inspected. The Ship Structure Committee determined there was a need and initiated a project to develop a guide to aid in the proper application of various NDT methods to cover such non-butt welded joint configurations commonly used in ship and other marine structures. This report is that guide. It does not set acceptance standards but does provide a meaningful way by which such standards may be applied.

To make the guide useful to production and inspection personnel in shipyards, the technical support data was placed in a separate report - SSC-254 - under the same title but as Part Two.

Comments and suggestions for additional research topics on problem areas will be most welcome.

W. M. Benkert
Rear Admiral, U.S. Coast Guard
Chairman, Ship Structure Committee

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Final Report

on

Project SR-219, "Nondestructive Test (NDT) Guide for Welded Steel Joints"

A GUIDE FOR THE NONDESTRUCTIVE TESTING OF NON-BUTT WELDS IN COMMERCIAL SHIPS

PART ONE

by

R. A. Youshaw and E. L. Criscuolo

Naval Surface Weapons Center

under

Department of the Navy
NSWC Project NAVSHIP #00-0141

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U. S. Coast Guard Headquarters
Washington, D.C.
1976

ABSTRACT

This guide has been prepared to provide nondestructive test information for application to all weld joints other than butt welds. It covers welds in the thickness range 1/2" to 2 1/2" and considers the five basic inspection methods: Visual, Radiography, Ultrasonic, Magnetic Particle, and Dye Penetrant.

It should be noted that most joints in commercial shipbuilding other than butt welds are not nondestructively inspected. This guide does not imply that inspection of such joints is required. This is determined by contractual agreements. However, the shipbuilder may wish to conduct tests above and beyond contractual requirements in order to ensure detection of flaws as early as possible thus eliminating costly rework at a later stage.

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SHIP STRUCTURE COMMITTEE

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A GUIDE FOR THE NONDESTRUCTIVE TESTING OF NON-BUTT WELDS IN COMMERCIAL SHIPS

This report is published in two parts: Part 1 is the guide for the nondestructive testing of non-butt welds in commercial ships. Part 2 documents the technical considerations involved in preparing that guide.

This work was sponsored by the Naval Ship Systems Command under the direction of the Ship Structures Committee and was accomplished by the Nondestructive Analysis Group of the Physics Research Department.

The authors acknowledge the guidance and assistance given by Messrs. R. W. Rumke, W. W. Offner, S. Goldspiel, G. E. Kampschaefer, F. Dashnaw, Prof. J. E. Goldberg, and CDR C. S. Loosmore, USCG.

Appreciation is expressed to the shipbuilding facilities who participated in the survey for the many helpful suggestions they offered.

John B. Wilcox

J. B. WILCOX
By direction

NOTES

INTRODUCTION

This guide considers the methods of nondestructive testing suited to the inspection of ship welds. Depending upon the circumstances and the degree of criticality, any of these methods may be more appropriate than any of the others. It is emphasized that the different methods are not competitive. In some cases more than one method of nondestructive testing may be required for complete inspection. In most cases, a higher level of quality assurance is obtained by using complementary inspection methods.

A brief review is made of the principles of application for each of the methods of nondestructive testing suited to ship weld inspection. This is for the purpose of creating an awareness of technical considerations which can affect the quality of inspection. Specific joint configurations are then considered in regard to the types of flaws frequently encountered in that type joint, the inspection procedures recommended for detecting each type flaw, and the procedure for applying each inspection method to the different joints.

The nondestructive testing procedures are intended for use in conjunction with contractual agreements which specify the acceptance criteria for each method.

NONDESTRUCTIVE TESTING METHODS

A general discussion of nondestructive testing is presented. This includes basic principles and the capabilities and limitations inherent with each method. These apply to all welds regardless of joint configuration.

Mandatory requirements are imposed only where the basic principles of application are involved. Recommendations are made in accordance with recognized good practice. Precautionary statements are included where appropriate to create an awareness of potential difficulties.

Visual Inspection

General. For many weldments which are not critical, assurance of satisfactory weld quality and good workmanship are determined by visual inspection. In addition, the techniques of visual inspection can and should be applied to those weld joints considered critical and which will require more sophisticated techniques of nondestructive testing. The advantages are obvious; visual inspection is quick, easy to apply, it can be done on site at any stage from fit-up to completion, and it is comparatively inexpensive. Properly applied visual inspection can aid significantly in maintaining satisfactory workmanship.

Inspection Before Welding. Visual inspection before welding provides assurance of proper joint preparation and that the surfaces to be welded are clean, dry, and free from accumulations of foreign materials such as grease, oil, excess paint, or heavy rust. A feeler gauge can be used to ascertain correct root gap separation. Edge chamfers and correct alignment may be checked with shapes cut to the desired angle.

Inspection During Welding. Inspection during welding is done with multipass welding and is directed toward detecting an unacceptable condition before performing subsequent welding. Each pass should be carefully examined for cracks. Subsequent welding will not usually result in crack removal and the thermal stresses involved in welding may cause the cracks to propagate into the base material thus complicating repair. In addition, partly welded or back-gouged welds should be inspected for complete removal of unfuzed abutting root faces before the deposition of subsequent filler material.

Successive passes of multipass welds can also be visually inspected for unremoved slag. If not removed, the slag may remain in the weld. Complete slag removal is usually most troublesome in the root pass.

The heat of welding will sometimes cause laminations in the base metal to open up, thus making them visible. If this condition is detected and if it is controlled in degree by specifications, the extent of the lamination can be more extensively investigated by another method of nondestructive testing such as ultrasonics.

Inspection of the Finished Weld. The finished weld can be visually inspected for conformance to the required weld throat, limitations on concavity or convexity, weld distortion, fillet symmetry and misalignment. Also, the degree of undercut or excessive reinforcement can be measured.

These aspects of visual inspection can quickly and accurately be accomplished with any of several pocket-size gauges. Figure 1 illustrates two gauges which are commercially available.

The completed weld may also be inspected for excessive weld splatter or arc strikes when appearance is of importance. Weld discontinuities may also be detected. The detection of cracks or other weld flaws may suggest further examination at particular locations using more sophisticated methods of nondestructive testing.

Magnetic Particle Inspection

General. The magnetic particle method can be used to nondestructively inspect welds providing that the base metal and weld metal are both ferromagnetic. The basic principle of magnetic particle inspection is that tiny magnetic particles placed upon the surface of a magnetized material will move to discontinuity sites in response to the strong leakage magnetic fields at such locations. The detection of discontinuities is limited to those which extend to or which lie only slightly beneath the surface.

Generating the Magnetic Field. The magnetic field is most often created by passing low voltage-high amperage current through the work piece with a pair of prods. Another way to generate a magnetic field is by the use of electromagnets (Yokes). When prods are used, the electrical current generates a circular magnetic field which is perpendicular to the path between the prods, Figure 2. Such a field is suited to the detection of discontinuities oriented parallel to the path between the prods. Thus, a weld may be searched for longitudinal flaws by positioning the prods along the length of the weld. If irregularities on the weld bead prevent good prod contact, the prods may be placed on the base metal, on opposite sides of the weld, close to the weld. Transverse flaws may be detected by placing the prods on the base metal on approximately opposite sides of the weld.

The magnetic field can be generated using direct current, alternating current, full-wave three-phase rectified current, or half-wave rectified single phase current. However, the test results will differ according to the type of current used. Alternating current, for example, is limited to detecting surface discontinuities while the response when using direct current can include indications related to near subsurface flaws.

Prod Spacing. The electrical current required for proper magnetization must be selected according to the prod spacing. Between 100 and 125 amperes of electrical current are required for each inch of prod spacing.

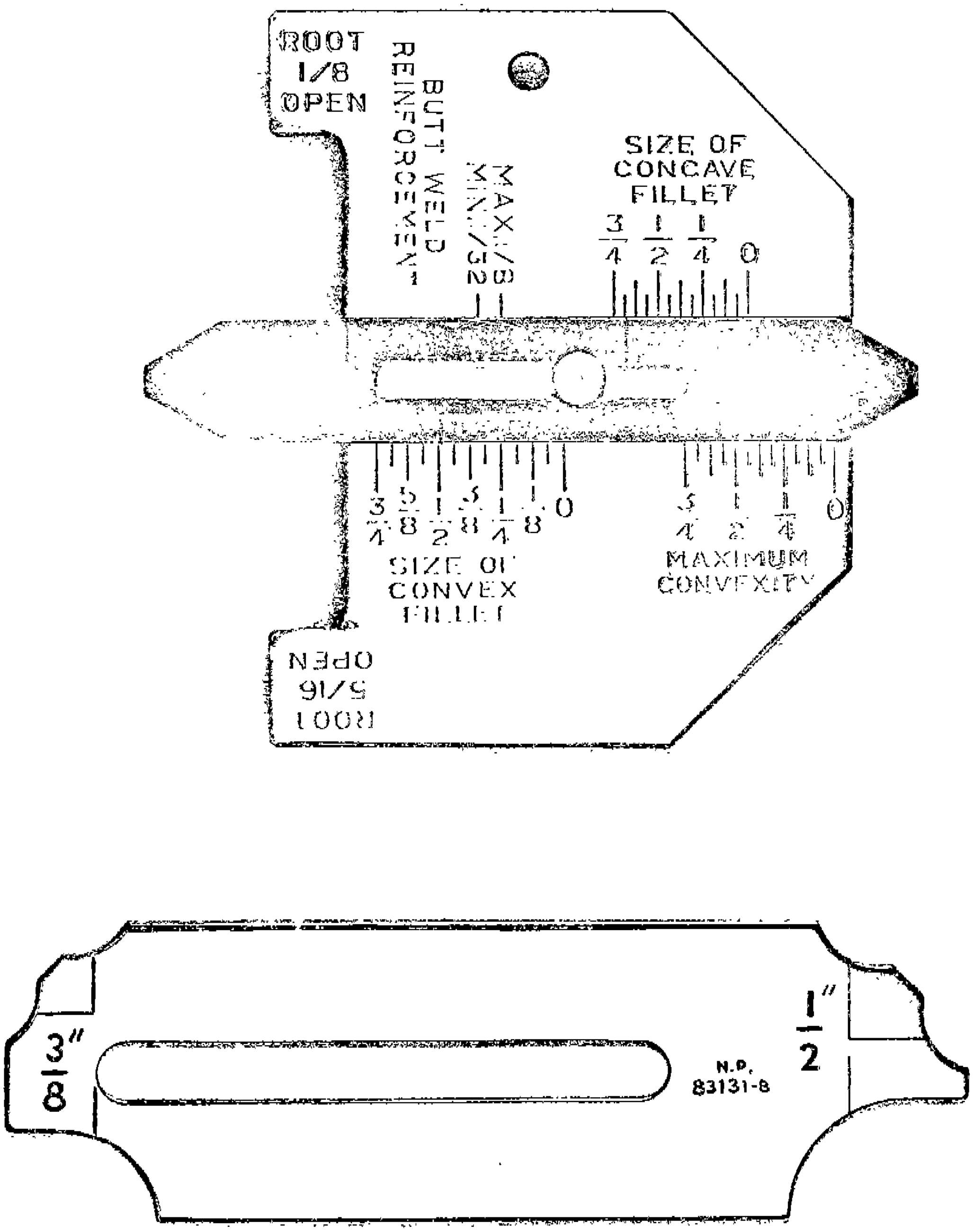

FIG. 1 TYPICAL GAUGES FOR INSPECTING FILLET WELDS

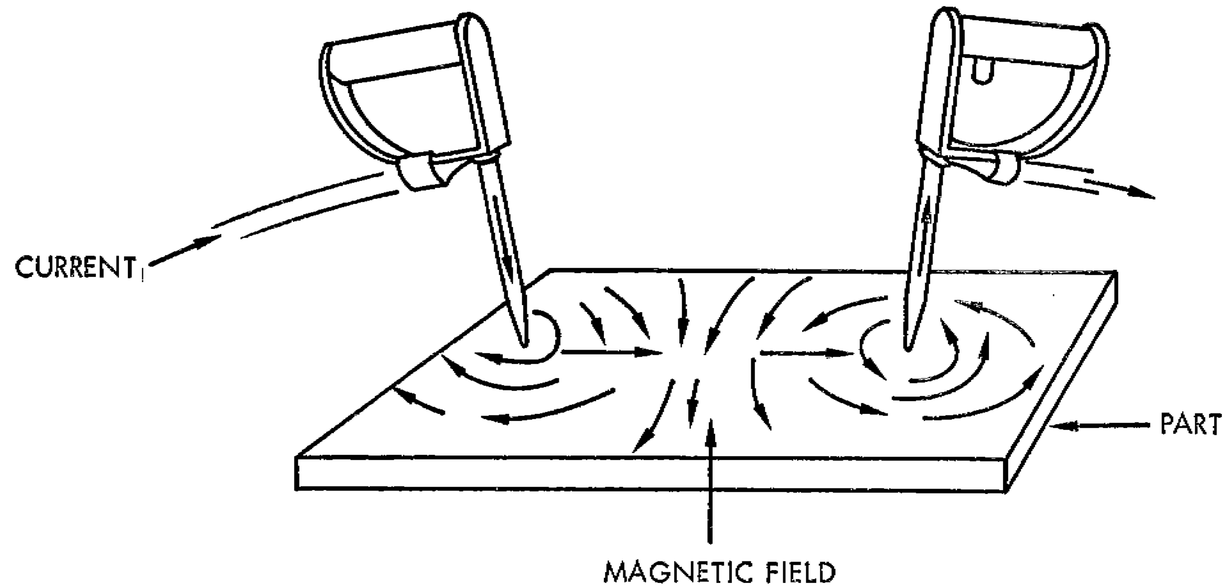

FIG. 2 CIRCULAR MAGNETIZATION INDUCED BY PASSING CURRENT THROUGH PLATE MATERIAL USING PRODS

For welds in excess of 3/4" plate thickness, the current is increased an additional 25% to 50%. Table I lists the required magnetization currents according to prod spacing and section thickness. It is recommended that the equipment include an ammeter to ensure adequate current for proper inspection.

For weld inspection, the prod spacing should not be closer than 3"; and prod spacings in excess of 12" are impractical because of excessive current requirements. It is recommended that prod spacing between 4" and 8" be used.

Prod Positioning. It is very important to maintain good contact to prevent arc strikes and localized heating at the prod contact locations. This can be achieved by using pressure with hand inspection or by utilizing clamping devices. These aspects of magnetic particle testing are especially important when inspecting heat hardenable steels to avoid creating hard spots or cracks.

A remote control switch should be provided to enable the operator to turn the current on after the prods have been properly positioned and to turn the current off before the prods are removed.

Surface Preparation Requirements. The as-welded condition is usually satisfactory for magnetic particle testing without further preparation, except that paint on the base metal must be removed from the prod contact locations - ordinarily by hand grinding or wire brushing. However, test results are affected by contaminants such as dirt, grease, or scale and some surface preparation may be necessary. A forceful air blast directed on the test area may be useful in removing dirt and scale. When the test area is contaminated with oil or grease, it should be cleaned with a suitable solvent. Sand blasting is very effective.

Magnetic Particle Requirement. The magnetic particles consist of a finely divided ferromagnetic material which should be of high permeability and low retentivity. The particles should be selected such that the size and color provide adequate sensitivity and contrast for the detection of the discontinuities of interest.

Magnetic Particle Test Procedure. After the prods have been firmly positioned and the current has been turned on, the magnetic particle powder is applied as a light dust. This can be with a dusting bag, an atomizer, or a spray gun. Then with the current still flowing, a gentle stream of air should be directed on the inspection area to

TABLE I - ELECTRICAL CURRENT REQUIREMENTS FOR MAGNETIC PARTICLE INSPECTION

PROD SPACING (INCHES)	AMPERES SECTION THICKNESS	
	UNDER ¾"	¾" AND OVER (AMPERES)
3	300–400	375–500
4	400–500	500–625
5	500–625	625–775
6	600–750	750–900
7	700–875	875–1100
8	800–1000	1000–1200
9	900–1100	1100–1300
10	1000–1200	1200–1400
11	1100–1300	1300–1500
12	1200–1400	1400–1600

remove excess powder and enhance discontinuity indications. This can be done with a low velocity air hose or with a hand operated squeeze bulb.

The inspection of long welds requires some overlap between adjacent weld segments.

The Evaluation of Indications. Indications are analyzed and evaluated on the basis of size, shape, sharpness, and the degree of particle accumulation. Cracks usually produce strong indications and are readily identified. Lack of fusion will also produce a strong indication and can be identified by its location at the edge of the weld.

Although discontinuities such as slag, porosity, and lack of fusion located slightly beneath the surface may produce indications, these are fainter and less distinct than those extending to the surface. The type of current being used must be considered in the evaluation of such indications.

Nonrelevant Indications. Indications may also be obtained from undercut or abrupt irregularities on the weld surface. These are not usually distinct or intense and can often be correlated with visual inspection. Under certain conditions, the heat affected zone may produce an indication. This should not be considered a weld flaw. Similarly, there are combinations of base metal and filler materials which differ markedly in magnetic properties. Weld joints involving such combinations produce sharp and intense linear indications at the boundaries of the weld.[1] This type of indication is unrelated to the soundness of the weld.

Radiography

General. Radiography is a useful tool for the inspection of critical welds. It provides a visual presentation, an internal inspection and a permanent record. A major disadvantage in shipbuilding application is that this method requires access to both sides of the weld. Also, in regard to non-butt welds, interpretation of the radiograph becomes more difficult as the geometry deviates from planar to the

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[1] Such a pattern might be obtained when a weld is made involving a ferritic (magnetic) and an austenitic (non-magnetic) steel.

more complex configurations. This aspect of technique is of paramount importance. While other technique factors such as kilovoltage (kV), milliamperage (mA), exposure time, distance, etc. are important, a very limited discussion is given here since the information can be found elsewhere.[2]

Radiation Source Energy. The selection of the radiation source for a particular thickness weld is of major importance. If the energy of the source is too high for a given thickness, then low contrast and poor radiographic sensitivity results. Figure 3 is a general guide for the selection of the maximum acceptable voltage for a given thickness. It is not necessary to be on the curve. In general, better radiographic sensitivity is achieved in the acceptable region of the graph. The upper part of Figure 3 shows the recommended limits of steel thickness when using iridium or cobalt isotopes.

Factors Affecting Radiographic Sensitivity. The radiation source to film distance, the size of the focal spot, and the distance of the front surface of the object to the film are important in determining the sharpness of a radiograph. These parameters are interrelated and are presented in Figure 4. The minimum distance from the radiation source to the film is given for distances between the source side of the object and film. For smaller source or focal spot sizes, the source to film distance may be reduced. Care must be taken to be sure distortion does not interfere with interpretation of the radiograph.

Selection of Film. There is a wide selection of film available for industrial radiography. The use of a particular film is primarily guided by the quality level of inspection that is specified and secondarily by factors such as material thickness or energy of radiation source. In general for the initial exposure, use of the fastest nonfluorescent film types available will be found to produce a 2-2T quality level of inspection.

Where the geometrical conditions of the weld necessitate a higher level of inspection or where scatter conditions may degrade the

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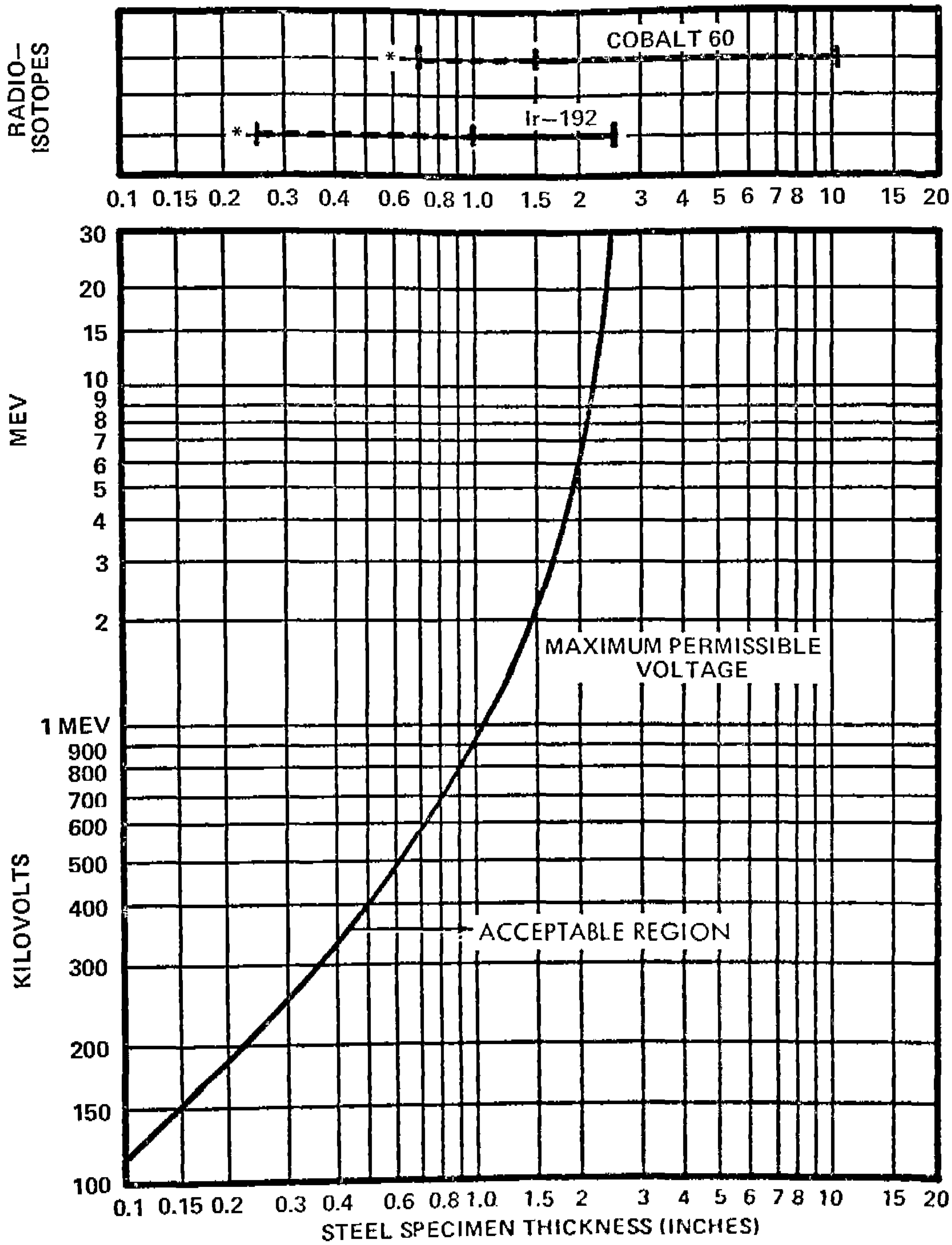
[2] American Welding Society, WELDING INSPECTION, 1968



* BROKEN LINE INDICATES MARGINAL SENSITIVITY

FIG. 3 MAXIMUM VOLTAGE OR RADIOACTIVE ENERGY FOR MINIMUM STEEL THICKNESS

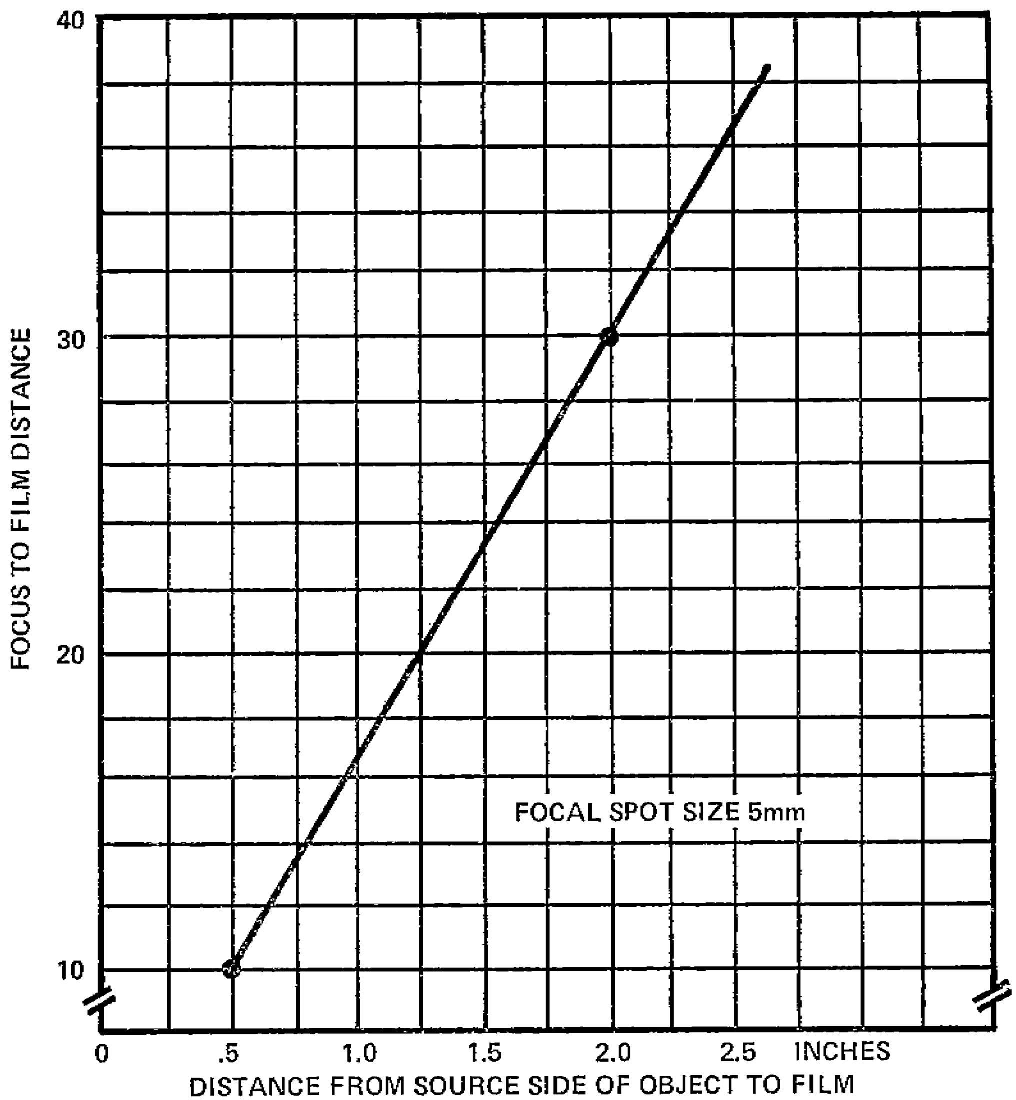


FIG. 4 MINIMUM DISTANCE FROM RADIATION SOURCE TO FILM

radiographic quality with the above films, other film are available that have a finer grain and can produce a satisfactory quality radiograph.

Screens. Screens are uniform thickness of high atomic numbered material, usually lead, placed in the cassette so as to be in intimate contact with the film. The screens by their intensifying action help reduce exposure time and also aid in reducing the effect of scatter. Usually lead screens are .005" thick when used as front screens and .010" thick when used as back screens. Their use in radiography of ship welds should be mandatory. The use of lead-film combinations that are available commercially is also satisfactory when it displays the required radiographic quality.

Filters. Filters are materials of high atomic number, usually lead, that are placed between the radiation source and cassette so as to minimize the effect of scatter. Filters are usually placed immediately in front of the cassette. Their use is optional and is usually not required when radiographing simple joints but may be of value in radiographing corner or other more complex joints.

Penetrameters. It is recommended that an image quality indicator that conforms to ASTM E142-68 be used. This penetrameter consists of a plaque made of radiographically similar material to the weldment and it contains three drilled holes with diameters one, two, and four times the plaque thickness. These holes are used in conjunction with the plaque thickness to establish various image quality levels as given in Table II. The 2-2T quality level is generally used for most inspection. The penetrameter is placed on the source side of the weld. If it is not possible to place the penetrameter along side the weld, it may be placed directly on the weld reinforcement. If the surface ripples interfere with the visibility of the hole, the reinforcement may be smoothed by grinding or other suitable means. Only a minimum amount of metal should be removed.

Film Density Requirements. A complex joint configuration may cause a large film density variation. If the film density falls off along the length of the weld, the radiograph should not be interpreted beyond the area on a film where the density varies more than -15% of the density in the center of the film.

If the film density varies more than -15% or +30% from that on the penetrameter, two penetrameters may be used to qualify the radiograph. If an acceptable image quality level is shown by the penetrameter located at the dense part of the radiograph and by the other placed

TABLE II - RADIOGRAPHIC LEVELS OF INSPECTION

LEVEL OF INSPECTION	PENETRAMETER THICKNESS	MINIMUM PERCEPTIBLE HOLE DIAMETER	EQUIVALENT PENETRAMETER SENSITIVITY PERCENT
1–1T	1/100 (1 PERCENT) OF SPECIMEN THICK-NESS	1T	0.7
1–2T		2T	1
2–1T	1/50 (2 PERCENT) OF SPECIMEN THICK-NESS	1T	1.4
2–2T		2T	2.0
2–4T		4T	2.8
4–2T	1/25 (4 PERCENT) OF SPECIMEN THICK-NESS	2T	4

at the lower density portion, then the two penetrameters serve to qualify the portion of the radiograph between the two density values. (Note: Density measurements are made along the center line of the weldment).

Film Reading Requirements. Radiographs should be read in a room with subdued lighting. The background lighting should be of less intensity than the area of interest on the radiograph. Care should be taken to prevent as little light as possible from being reflected off the surface of the radiograph.

The intensity and masking of the illuminator is important. The illuminator should be able to transmit at least $30 cd/m^2$ (0.33 foot lamberts) through the area of interest in the radiograph. A mask over the illuminator should be used to shield very bright areas from the film readers' eyes.

The film readers' eyes should be examined at least once a year for ability to see small detail at a normal reading distance of 400mm. The reader should be able to read good print type of 0.5mm height or better at this distance.

Ultrasonic Inspection

General. Ultrasonic vibrations can be used to nondestructively examine the interior of welds. This is done by introducing high-frequency sound waves into the weld volume with a transducer which acts reversibly to detect the sonic echoes resulting from reflecting surfaces within the test object. The echoes are presented on an oscilloscope display and by careful analysis of the oscilloscope pattern, the size and location of internal discontinuities can be deduced.

Transducers. Steel welds may be ultrasonically tested with frequencies between 1 and 5 Mhz. The frequency of 2.25 Mhz is especially well-suited to steel and is recommended. Round transducers are favored for straight (longitudinal waves) testing, and rectangular transducers of a ratio 2:1, width to height, are recommended for shear waves. In either case, the active element (manufacturers specification) should not exceed one inch.

Couplants. Ultrasonics will not propagate through an air gap and some type of liquid is required to couple the transducer and work piece. The couplant should be removed upon completion of inspection.

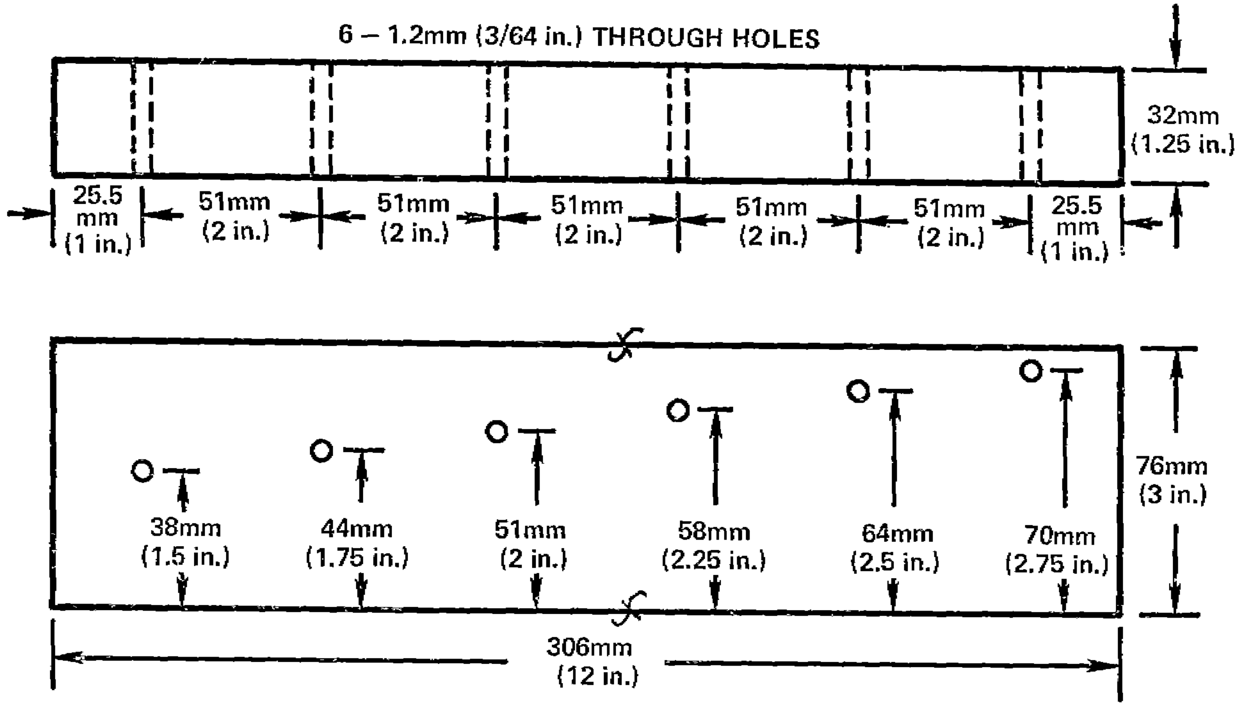
Surface Preparation. The surfaces where the probe makes contact with the weld or base metal should be suitable for good acoustical coupling. Plates with loose scale, flaked paint, excess rust, or pitting will require some preparation. Weld splatter can interfere with ultrasonic inspection and must be removed from transducer contact locations.

Ultrasonic Equipment. The ultrasonic instrument used in weld testing employs an "A-scan" presentation. The circuitry for the instrument should include controls for providing continuously increasing signal amplification with respect to time or distance of travel. A calibrated decibel attenuator is recommended. Battery-powered equipment should contain an alarm to warn of battery depletion prior to instrument shut off due to battery exhaustion.

Instrument Calibration. The ultrasonic method is essentially qualitative, but it can be made quantitative by comparing signal amplitudes with reflectors of known shape, orientation, and area. This can be done by calibrating the instrument with a suitable test block. Figure 5 illustrates the basic test block used for instrument calibration for ship hull weld inspection using shear waves. This test block is also suitable for instrumental calibration when using longitudinal waves. Instrument calibration is identical to the procedure for shear waves as set forth in Appendix 1, SSC-213 A GUIDE FOR ULTRASONIC TESTING AND EVALUATION OF WELD FLAWS (The American Bureau of Shipping has also set forth procedures for applying ultrasonic inspection to hull welds. RULES FOR THE NONDESTRUCTIVE INSPECTION OF HULL WELDS, 1975 (in publication). These differ slightly from SSC-213.) The transducer is positioned as shown in Figure 6. Calibration should be performed each time the instrument is used and recalibration is recommended following any interruption of electrical power.

Discontinuity Length Determination. The length of a discontinuity is determined by maximizing the signal and moving the transducer parallel to the discontinuity and away from the position of maximum signal. The points where the signal amplitude is reduced to one-half are defined as the extremities. The center line of a shear wave probe and the center of a straight beam probe are used for determining the extremities of a discontinuity.

Ultrasonic Signal Evaluation. The concepts of ARL (amplitude reject level) and DRL (disregard level) as used in shear wave testing of butt welds, Appendix I, are also valid when using longitudinal waves and for the inspection of non-butt welds. However, the permissible length of discontinuity for each category may differ for non-butt welds depending upon the degree of criticality and should be specified.



MATERIAL – LOW CARBON STEEL

✓ – SURFACE FINISH 6.3 X 10^{-6} RMS MICROMETERS (250 RMS MICROINCHES)

FIG. 5 TYPICAL TEST BLOCK FOR CALIBRATION OF THE ULTRASONIC INSTRUMENT

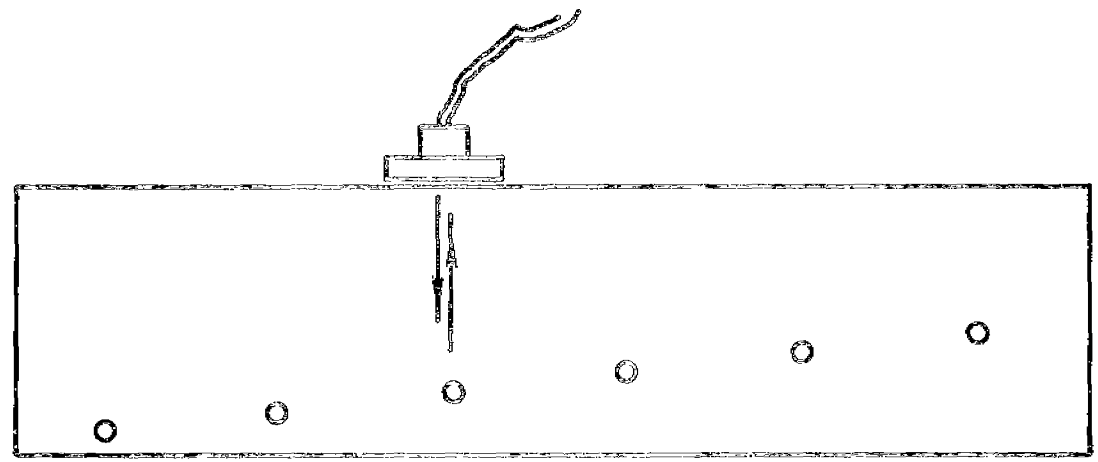


FIG. 6 POSITIONING OF THE TRANSDUCER FOR CALIBRATING THE ULTRASONIC INSTRUMENT WHEN USING LONGITUDINAL WAVE TRANSDUCERS

Dye Penetrant Testing

General. Penetrant testing is applicable to weld inspection where the discontinuities of interest extend to the surface. The method utilizes a brightly colored dye and a liquid with good properties for capillary action. The surface to be inspected is thoroughly cleaned and then saturated with the liquid. Sufficient time must be allowed for the liquid to penetrate tight cracks or crevices. After removing the excess liquid, some type of blotting material is applied which utilizes capillary action to withdraw the retained penetrant. Surface discontinuities such as cracks are enhanced by the contrast between the brightly colored dye and the blotting material and are readily detected by visual inspection.

Dye penetrant testing may be used on welds of any geometry or configuration providing certain fundamental principles are followed:

1. The weld must be clean and free of any material which might obstruct the penetrant. This includes materials which might have penetrated into the cracks or discontinuities of interest. Cleaning with a solvent suited to the removal of grease is recommended.

2. Ample time must be allowed for the liquid to penetrate tight cracks or narrow openings. Good practice requires a minimum waiting time of 15 minutes.

3. Ample time must also be allowed for the blotting material to develop the flaw indications. Several minutes is usually adequate; however, longer developing times are appropriate for situations where faint indications are observed.

QUALIFICATION AND CERTIFICATION OF NONDESTRUCTIVE TESTING PERSONNEL

Nondestructive testing should be performed only by properly qualified personnel. The American Society for Nondestructive Testing has published SNT TC-1A Supplements A, B, C, and D which establish criteria whereby personnel involved in nondestructive testing may be certified as qualified for the radiographic, magnetic particle, ultrasonic and penetrant testing methods. Three levels of qualification are defined:

NDT-Level I - An NDT Level I individual must have sufficient training and experience to properly perform the necessary tests. He shall be responsible to a person certified to NDT Level II or NDT Level III for the proper performance of the tests in the applicable method.

NDT-Level II - An NDT Level II individual shall be qualified to direct and carry out tests in the method certified. He must also be able to set up and calibrate equipment (where applicable), read and interpret indications, and evaluate them with reference to applicable codes and specifications. He shall be thoroughly familiar with the scope and limitations of the method, and shall have the ability to apply detailed techniques to products or parts within his limit of qualifications. He shall be able to organize and report nondestructive testing results.

NDT-Level III - An NDT Level III individual shall be capable of establishing techniques, interpreting specifications and codes, designating the particular test method and techniques to be used, and interpreting the results. He shall be capable of evaluating the results not only in terms of existing codes or specifications, but he also should have sufficient practical background in applicable materials technology to assist in establishing tests and acceptance criteria when none are otherwise available. It is desirable that he have general familiarity with other commonly used NDT methods. He shall be responsible for conducting examinations of NDT Level I and NDT Level II personnel.

The inspection methods discussed in this guide should be performed either by NDT Level II employees or by NDT Level I employees under the direction of an employee qualified to Levels II or III.

It is the responsibility of the shipyard to designate the level III employee. It is then his responsibility to ascertain proper education and training for employees certified as qualified for Levels I and II work. It is also the shipyards responsibility to determine that nondestructive testing performed on a contractual basis is done by properly qualified personnel.

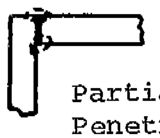
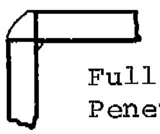
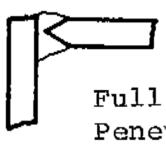
RECOMMENDED INSPECTION PROCEDURES FOR SPECIFIC JOINT CONFIGURATIONS

The American Welding Society recognizes four basic types of weld joint other than the butt - the corner, Tee, "X", and the lap. All other joints are varieties of these basic types. The techniques and procedures for these joints, as discussed in this guide, uses the simple case of right angle geometry. It is recognized that deviations from right angle geometry might be encountered in practice. Although the basic principles should be applicable, caution is recommended especially with ultrasonic inspection.

The selection of a nondestructive test method should be based upon the need to detect certain types of weld defects which are acceptable either because of service requirements or company standards. This guide lists the methods which are most suitable for detecting specific weld discontinuities and describes the procedures for applying each method to the various joint configurations.

Corner Joints

Corner joints may be welded either with complete penetration or intentional partial penetration. Joints welded with complete penetration may be prepared two ways as shown. The typical weld discontinuities for each of these categories and the nondestructive tests suited for the detection of each type flaw are presented below:

Joint Preparation	Defect	Methods for Inspection
 Partial Penetration	Unacceptable weld profile	Visual, weld gauge
	Cracks	Visual, magnetic particle
 Full Penetration	Unacceptable weld profile	Visual, weld gauge
	Cracks	Visual, magnetic particle
	Incomplete penetration	Radiography
	Lack of fusion	Radiography
	Slag	Radiography
	Porosity	Radiography
 Full Penetration	Unacceptable weld profile	Visual, weld gauge
	Cracks	Visual, magnetic particle
	Incomplete penetration	Ultrasonics
	Lack of fusion	Ultrasonics
	Slag	Radiography
	Porosity	Radiography
	Laminations	Ultrasonics

Visual inspection and the magnetic particle method are the primary nondestructive testing procedures used on corner joints designed for partial penetration welding.

Visual Inspection. Visual inspection provides:

1. A measurement of fillet size, Figure 7A.

2. The determination that fillet concavity and convexity are within specified limits, Figure 7B and Figure 8A.

3. Excessive reinforcement can be measured, Figure 8B.

4. Undercut can be measured with a depth gauge.

5. Visual inspection may also disclose cracks in the weld or adjacent material. Cracks are not usually permitted in weld joints and their detection should be called to the attention of quality assurance personnel for disposition.

Magnetic Particle Inspection. The magnetizing currents for different thickness of steel and for various prod spacings are given in Table I. When different thicknesses of base metal are involved, the average of the two thicknesses should be used in determining current requirements.

Magnetic particle inspection of the exterior of a corner joint is accomplished first by positioning the prods upon the weld and then by positioning the prods on opposite sides of the weld, Figure 9.

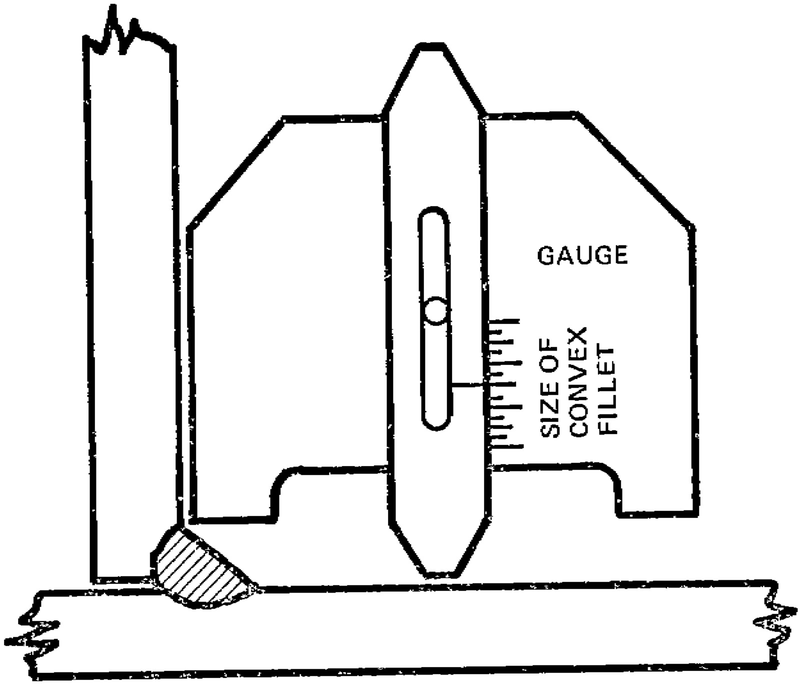
The interior of the joint should also be inspected. First, by placing the prods upon the weld and then by positioning the prods on approximately opposite sides of the weld.

The geometry of the interior of a corner restricts the positioning of prods on strictly opposite sides of the weld within the limits suggested for prod spacing. This difficulty can be resolved by off-setting the prods so that the path between them is at a slight angle to the weld. The deviation from strict perpendicularity to the weld will result in a slight decrease in sensitivity for detecting trans-verse discontinuities but the inspection will still be adequate.

Yokes are not recommended for use on corner welds because of geometrical restrictions and the difficulty of making good contact.

All cracklike indications should be considered significant. Depending upon the type of current used, some indications may be obtained related to the partial penetration. This should not be regarded as a weld defect.

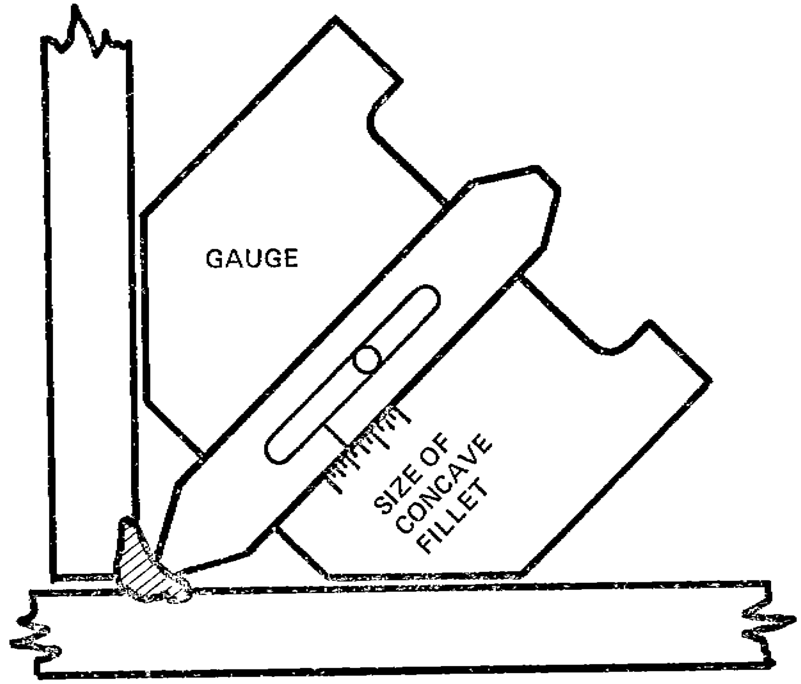
TO DETERMINE THE SIZE OF
A CONVEX FILLET WELD



PLACE GAUGE AGAINST THE TOE OF THE SHORTEST LEG OF THE FILLET AND SLIDE POINTER OUT UNTIL IT TOUCHES STRUCTURE AS SHOWN. READ "SIZE OF CONVEX FILLET" ON FACE OF GAUGE.

A

TO DETERMINE THE SIZE OF
A CONCAVE FILLET WELD

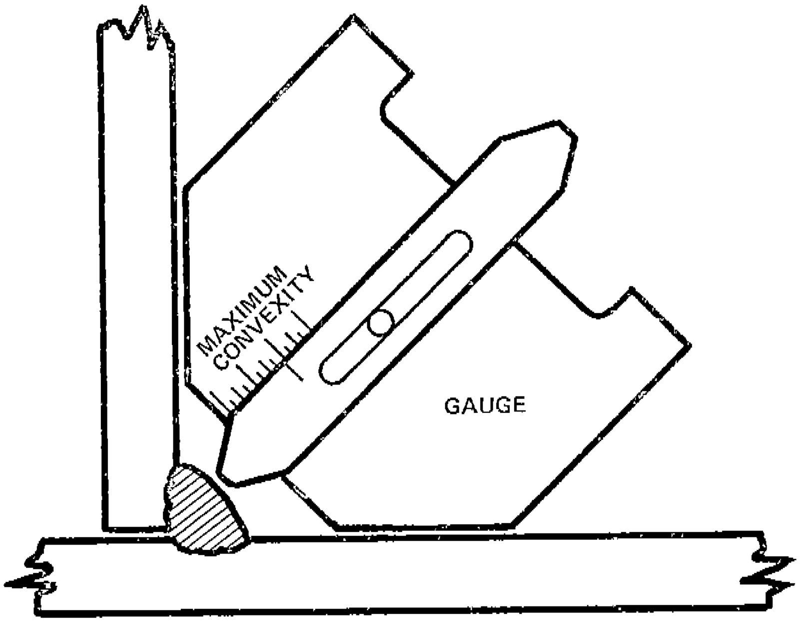


PLACE GAUGE AGAINST STRUCTURE AND SLIDE POINTER OUT UNTIL IT TOUCHES THE FACE OF THE FILLET WELD AS SHOWN. READ "SIZE OF CONCAVE FILLET" ON FACE OF GAUGE.

B

FIG. 7 PROCEDURE FOR MEASURING THE SIZE OF CONCAVE AND CONVEX FILLET WELDS

TO CHECK THE PERMISSIBLE TOLERANCE OF CONVEXITY



AFTER THE SIZE OF A CONVEX WELD HAS BEEN DETERMINED, PLACE THE GAUGE AGAINST THE STRUCTURE AND SLIDE POINTER UNTIL IT TOUCHES FACE OF FILLET WELD AS SHOWN.

FIG. 8A PROCEDURE FOR MEASURING THE PERMISSIBLE TOLERANCE OF CONVEXITY ON FILLET WELDS

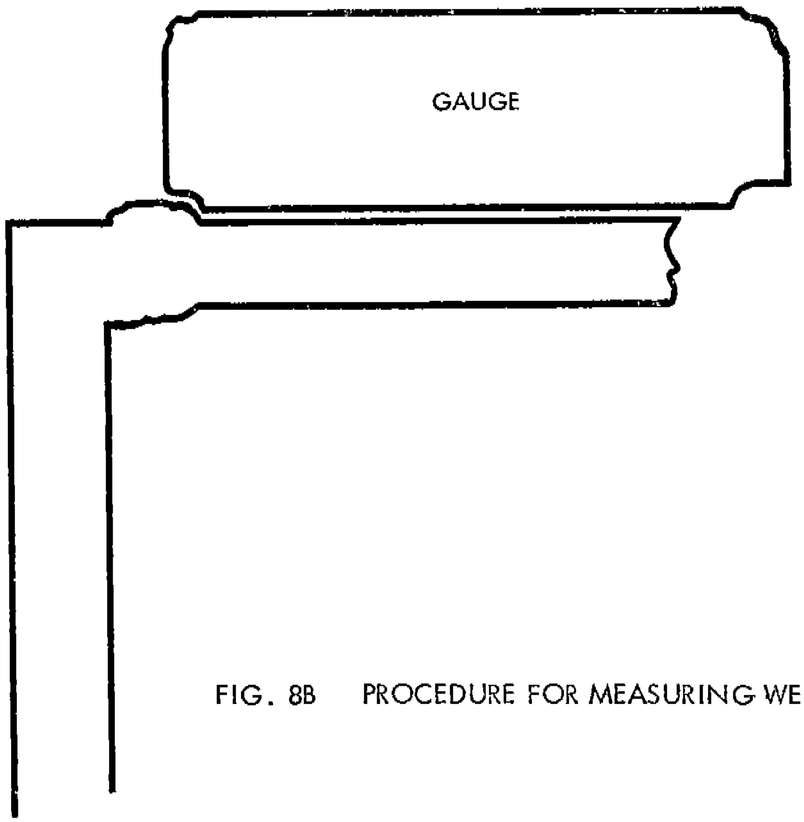


FIG. 8B PROCEDURE FOR MEASURING WELD REINFORCEMENT

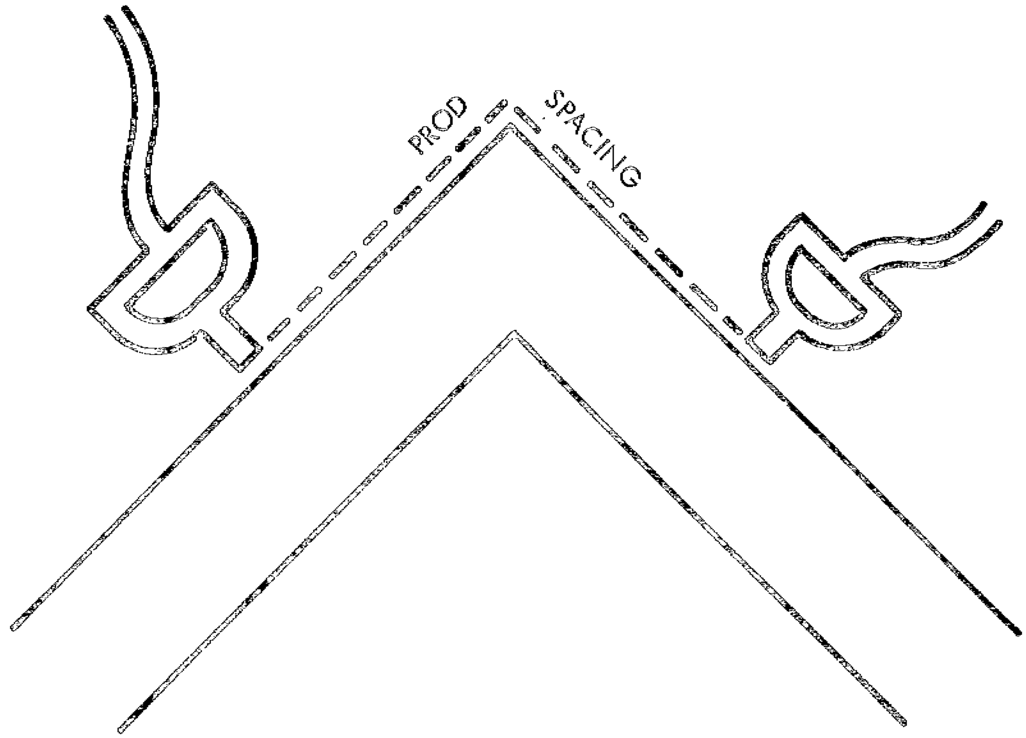


FIG. 9 PROD POSITION FOR MAGNETIC PARTICLE INSPECTION OF A CORNER JOINT

Ultrasonic Inspection. Joints prepared as shown in Figure 10 are not usually inspected with radiography because the geometry is unfavorable; however, ultrasonics can be used to inspect for lamellar tearing, incomplete penetration, and lack of fusion. For this application, the transducer must be smaller in size than the base metal thickness. It is recommended that the transducer diameter not exceed one half the base metal thickness. The transducer is first positioned on the adjacent base metal and note is made of the oscilloscope position of the signal corresponding to the back surface. The transducer is then positioned on the weld area, Figure 11. Ultrasonic signals obtained from the weld which are identical in screen position with that of the back surface may be attributed to either lack of fusion or incomplete penetration. Signals corresponding to a depth nearer than the back surface may be indicative of lamellar tearing. Flaws within the weld may be identified by their location at a depth greater than that of the base metal back surface.

Radiographic Inspection. Corner joints prepared as shown in Figure 12A do not offer the same accessibility of surface for ultrasonic inspection. This type of joint may be radiographed using the arrangement shown in Figure 12B.

Radiography of a corner at the recommended angle of 45° involves penetrating a thickness which is greater than the base metal thickness. As a guide in selecting a suitable penetrameter and an appropriate x-ray energy, it is recommended that the weld thickness be estimated as 1.2 multiplied by the base metal thickness. This estimated value for thickness can then be utilized in selecting a suitable x-ray energy using the graph of Figure 3.

The penetrameter should be placed directly upon the weld and arranged perpendicular to the radiation beam. Conversely, the lead identifying numerals should be placed on the cassette, but off to the side of the weld, Figure 12B.

Tee Joints

Tee joints may be welded either with complete penetration or with intentional partial penetration. The weld discontinuities for each category and the nondestructive test methods suited for detection of each type of flaw are given as follows:

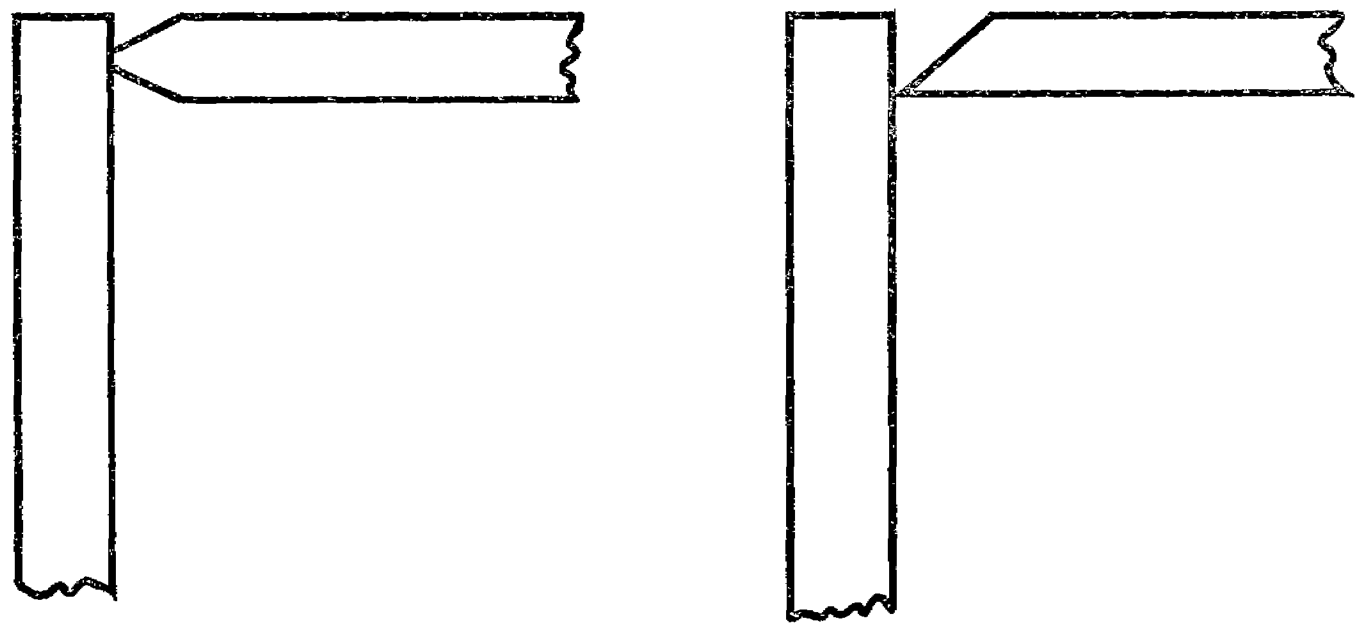


FIG. 10 JOINT PREPARATION FOR FULL PENETRATION CORNER JOINTS

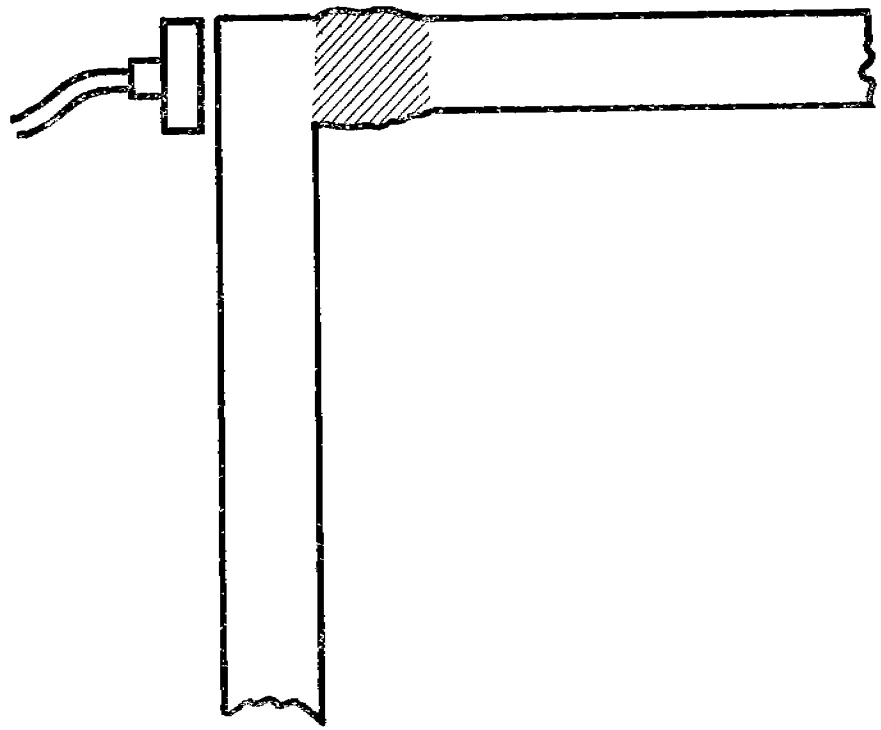


FIG. 11 ULTRASONIC PROCEDURE FOR THE INSPECTION OF FULL PENETRATION CORNER JOINTS

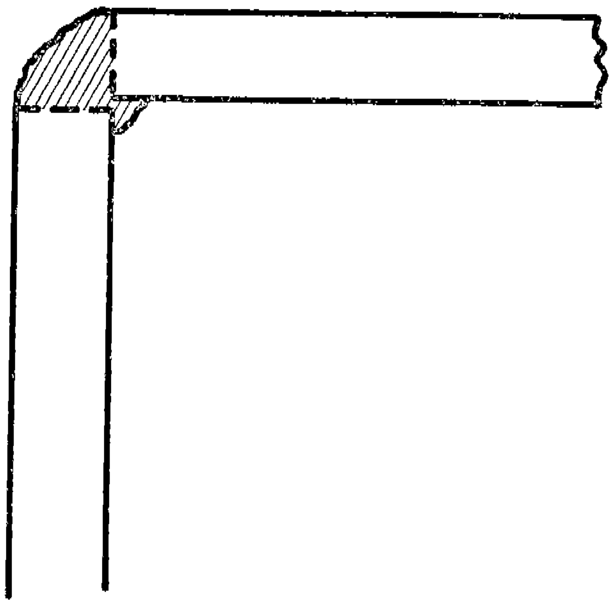


FIG 12A FULL PENETRATION CORNER JOINTS DONE WITHOUT CHAMFERS

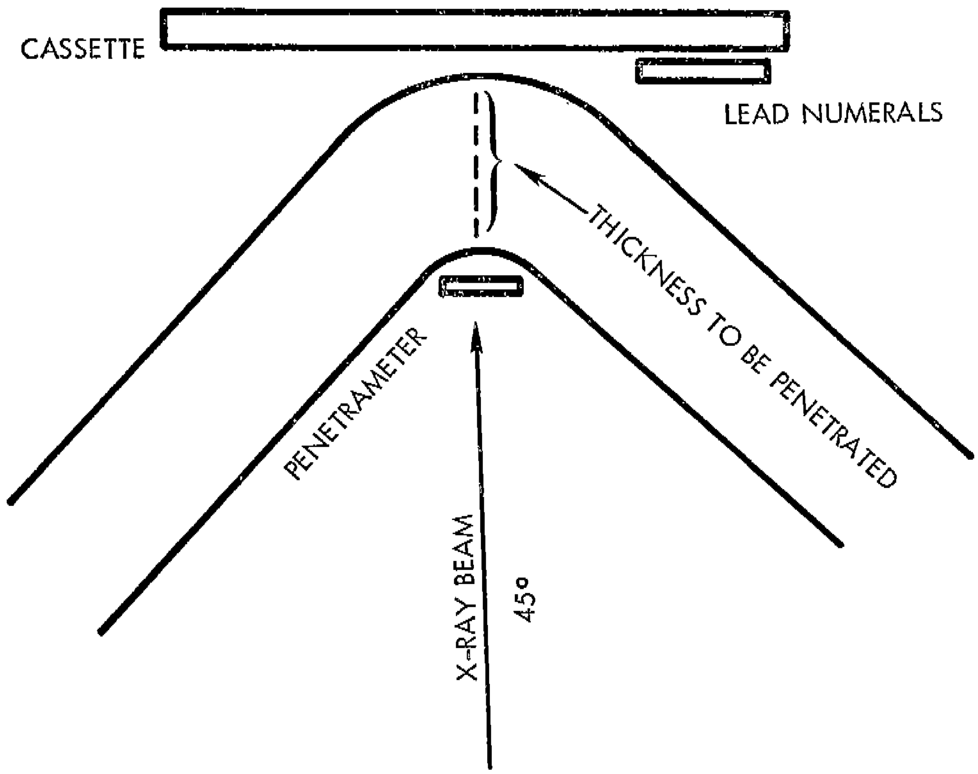
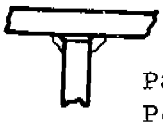
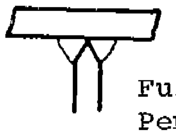


FIG. 12B TECHNIQUE FOR THE RADIOGRAPHIC INSPECTION OF FULL PENETRATION CORNER JOINTS

Joint Preparation	Defect	Methods for Inspection
 Partial Penetration	Unacceptable weld profile	Visual, weld gauge
	Cracks	Visual, magnetic particle
 Full Penetration	Unacceptable weld profile	Visual, weld gauge
	Cracks	Visual, magnetic particle
	Incomplete penetration	Ultrasonics, radiography
	Lack of fusion	Ultrasonics, radiography
	Slag	Radiography, ultrasonics
	Porosity	Radiography
	Laminations	Ultrasonics

Visual and Magnetic Particle Inspection. The visual inspection of T-joint welds is identical to the procedures described for corner joints. The magnetic particle inspection of a T-joint is identical in procedure to that for the interior of a corner joint. The requirements for magnetizing current are presented in Table I. For cases where the web and flange may differ in thickness, an average thickness is to be used in determining the applicable current requirements from Table I. T-joint welds which require critical inspection are usually tested using ultrasonics. Radiography may be useful as a supplemental technique, particularly for evaluating discontinuities detected with ultrasonic inspection.

Ultrasonic Inspection. Ultrasonics may be used to inspect both full penetration and partial penetration welds for lamellar tearing and underbead cracking. For this type inspection, the transducer (straight beam) is placed on the flange, Figure 13A, and the screen position of the signal obtained from the back surface is marked. Signals obtained from the weld zone at lesser depths may indicate lamellar tearing or underbead cracking. Full penetration welds can also be inspected for incomplete penetration and lack of fusion. These discontinuities produce signals at the same depth as the back surface of the flange. Discontinuities within the weld will produce signals which correspond to depths deeper than the back surface of the flange.

An angle beam transducer (45° is recommended) can be positioned as shown in Figure 13B to inspect for toe cracks or underbead cracking

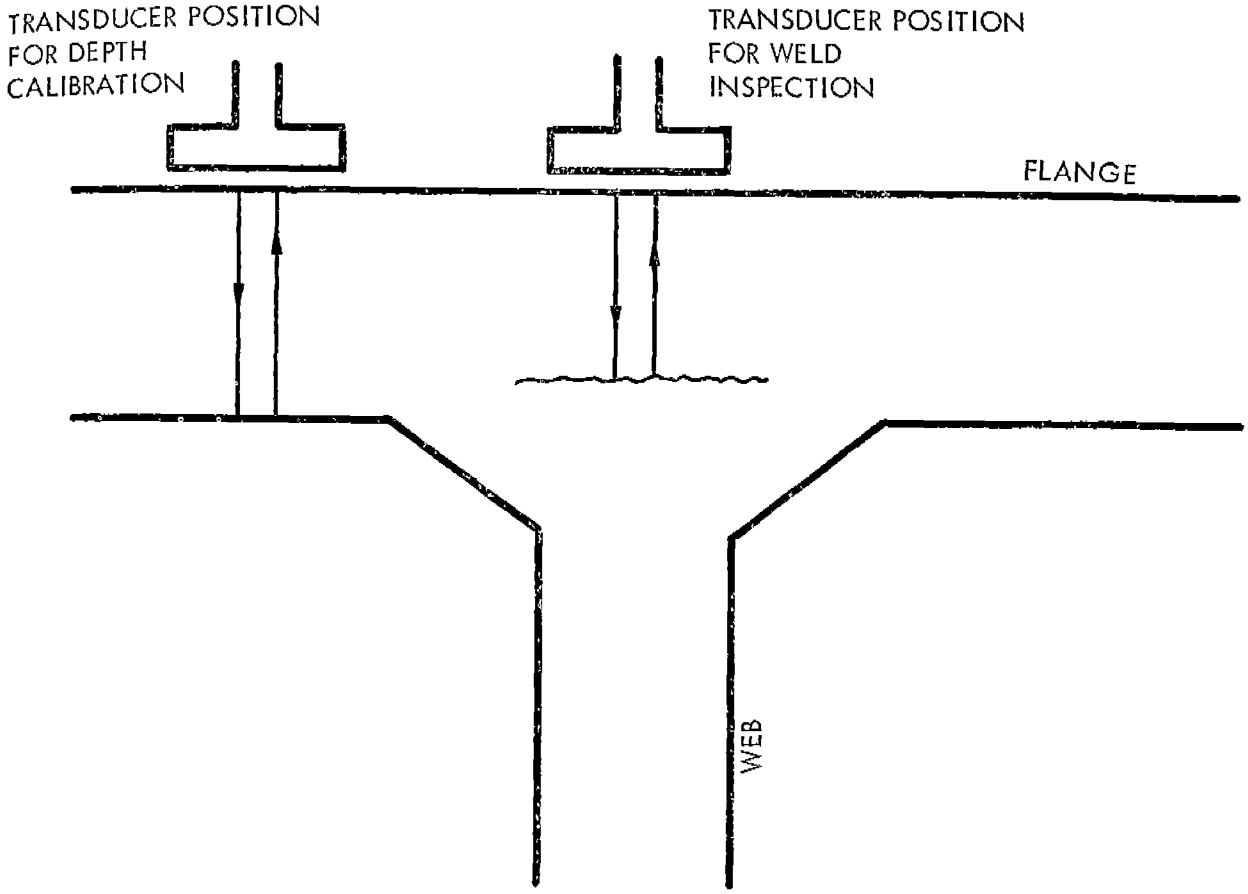


FIG. 13A ULTRASONIC PROCEDURE FOR THE INSPECTION OF T-JOINT WELDS WITH LONGITUDINAL WAVES

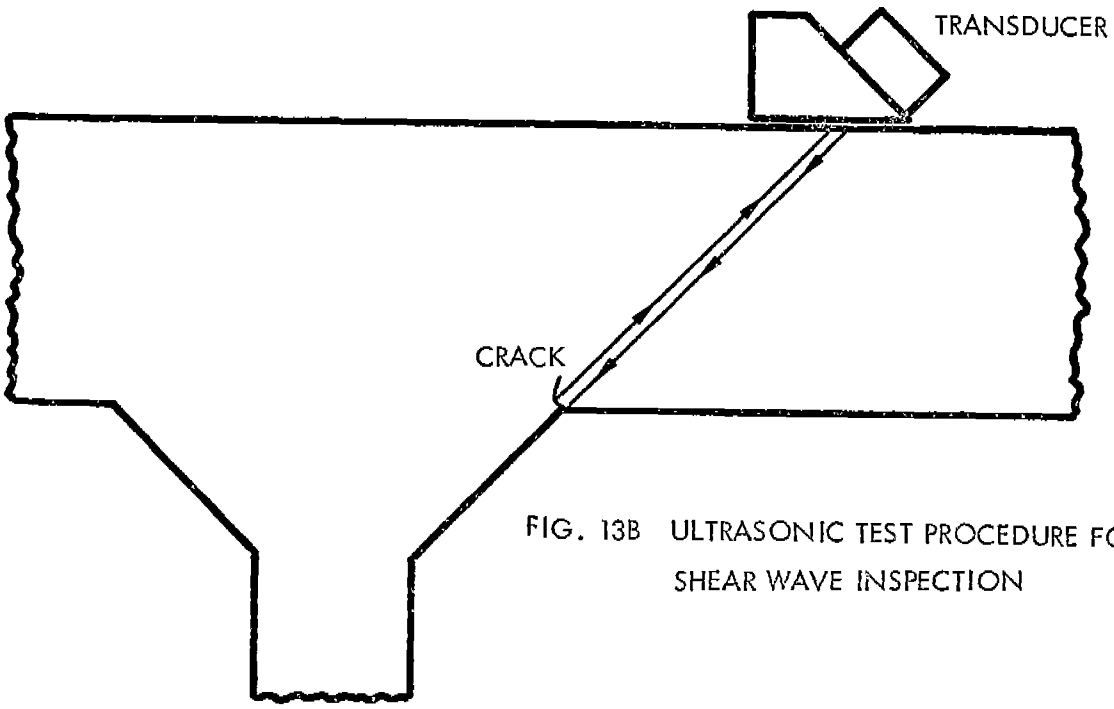


FIG. 13B ULTRASONIC TEST PROCEDURE FOR SHEAR WAVE INSPECTION at the edge of the weld. Before the angle beam search is done, a straight beam transducer is used to locate the edge of the weld. Simple geometrical considerations can then be used to determine the proper position for the angle beam transducer. For complete inspection, the weld should be searched from both sides.

The inspection for toe cracks may also be performed on the web, however, a web thickness of at least 1/2" is desirable.

Radiographic Inspection. T-joint welds may be radiographed using the arrangement illustrated in Figure 14. Full inspection requires that each fillet be radiographed separately.

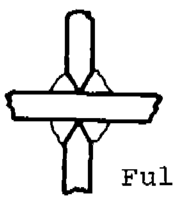
The radiography of a T-joint is complicated by the non-uniform thickness presented to the x-ray beam. In selecting a penetrameter, it is recommended that the thickness at mid-point of the weld be used. This thickness (for 45° angle) is determined by multiplying the flange thickness by 1.4 and adding to this the measured thickness of the weld throat, Figure 14A.

The penetrameter, lead identification numerals, and cassette, should be positioned as shown in Figure 14A.

Because of the differences in thickness to be penetrated by the x-ray beam, differences in film density are to be expected. Interpretation should be restricted to those areas of the weld which have a film density of at least 2.0. Complete inspection may require more than one exposure. These difficulties may be somewhat alleviated by selecting an x-ray inspection energy close to the upper limit in the graph of Figure 3.

"X"-Joint

X-joints are ordinarily prepared for full penetration welding. Typical flaws and the inspection methods suited for detecting these flaws are presented below:

Joint Preparation	Defect	Method for Inspection
 Full Penetration	Unacceptable weld profile	Visual, weld gauge
	Cracks	Visual, magnetic particle, ultrasonics
	Incomplete penetration	Ultrasonics, radiography
	Lack of fusion	Ultrasonics
	Slag	Ultrasonics, radiography
	Porosity	Radiography

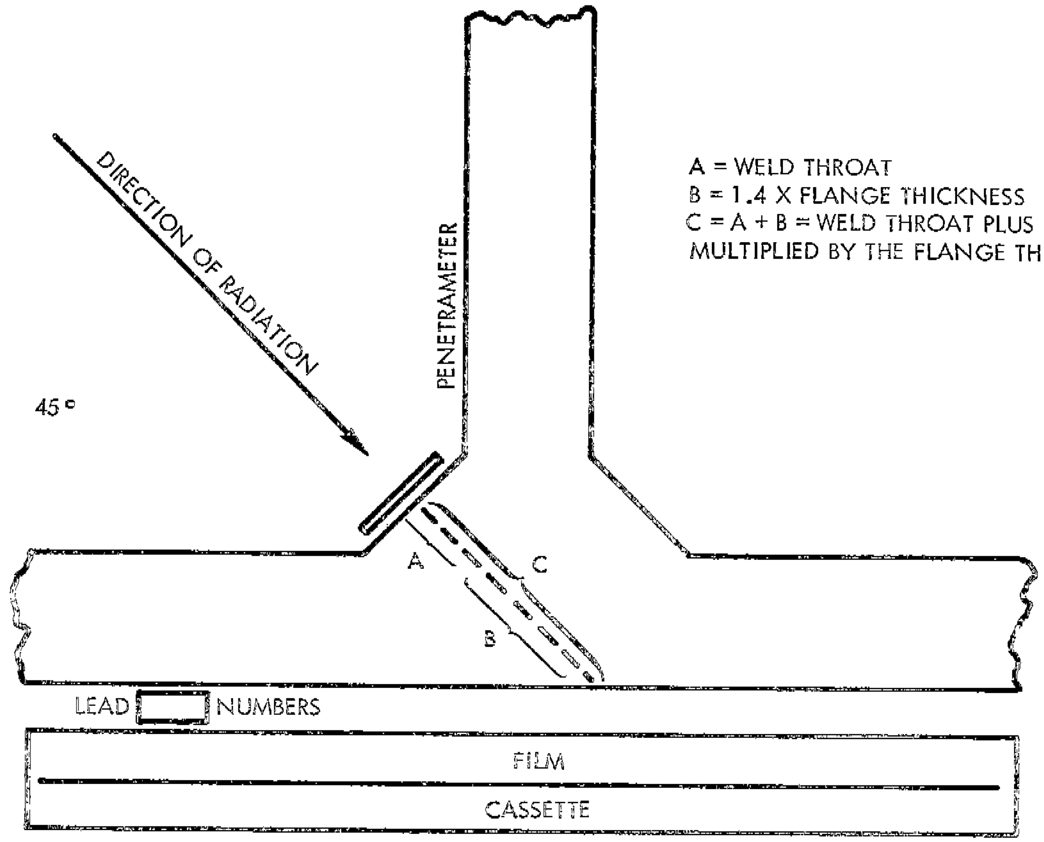


FIG. 14A ARRANGEMENT FOR THE RADIOGRAPHY OF T-JOINT WELDS

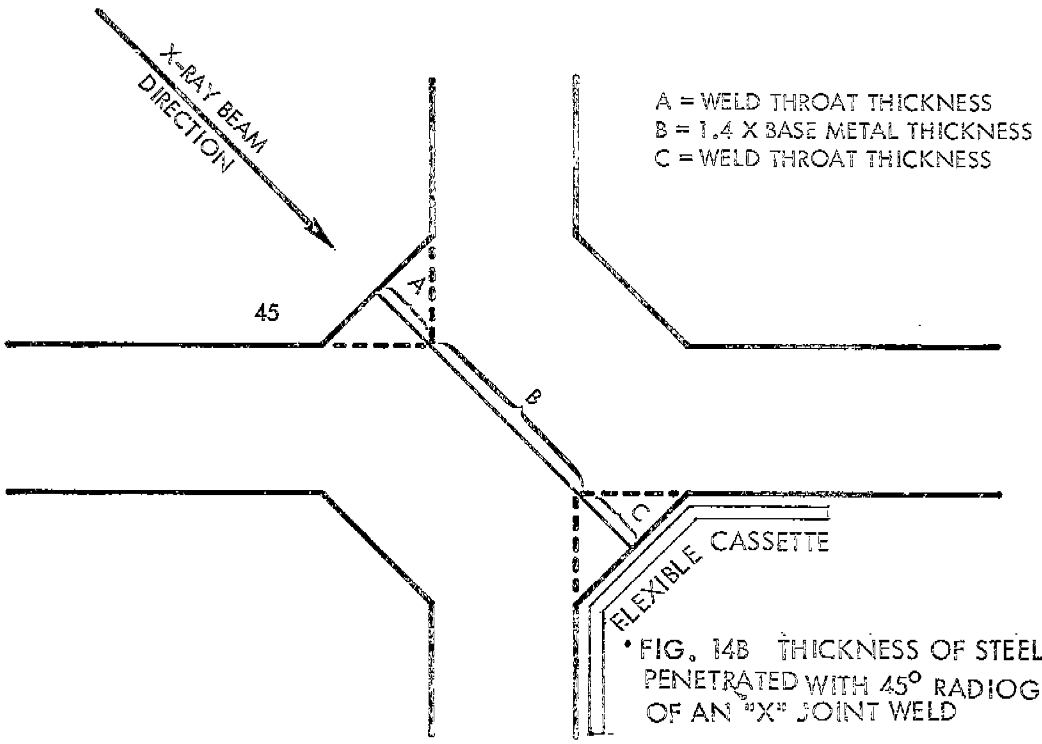


FIG. 14B THICKNESS OF STEEL TO BE PENETRATED WITH 45° RADIOGRAPHY OF AN "X" JOINT WELD

Visual and Magnetic Particle Inspection. Each of the four fillets of an X-joint constitutes a corner joint and visual and magnetic particle inspection techniques for these fillets are the same as those for corner joints. Critical inspection for subsurface flaws may be accomplished using radiography or ultrasonics.

Radiographic Inspection. Figure 14B illustrates the arrangement for radiography. Better quality radiographs are obtained by minimizing the object to film distance; and considering the restriction on accessibility, the film and cassette should be no wider than necessary but adequate to include the entire weld and adjacent heat affected zones on the radiograph. Radiography should be performed from mutually perpendicular directions. Directing the radiation beam at an angle bisecting the corner (45^{o}) will produce a radiograph with the most uniform film density.

For radiography at an angle of 45^{o}, the thickness to be penetrated is calculated by adding the angular path of the radiation through the base metal (1.4 multiplied by the base metal thickness) and the two weld throats, Figure 14B. The penetrameter should be placed directly on the weld and perpendicular to the x-ray beam. The identifying lead numerals should be placed on the cassette at the extreme end.

The calculated thickness to be penetrated can be utilized in conjunction with the graph of Figure 3 to select a suitable x-ray energy.

Radiography may be expected to reveal incomplete penetration, slag inclusions, and porosity. Favorably oriented cracks and lack of fusion may also be detected.

Ultrasonic Inspection. Ultrasonic inspection is restricted to angle beam techniques. Shallow angles (70^{o}) are recommended. The transducer is placed on the base metal and directed perpendicular to the weld, Figure 15. Calibration for distance or depth is necessary. Because the geometry is complex, caution must be exercised in evaluating all ultrasonic signals. In this regard, a test block of identical geometry and dimensions is useful. Further, artificial discontinuities may be introduced into the test weld to aid in evaluating ultrasonic signals obtained from production welds and to provide assurance of flaw detection capabilities. Complete ultrasonic inspection requires examination of the weld from all eight faces.

Lap Joint

Lap joints are usually fabricated as shown. The nondestructive tests suited for specific types of flaw detection are presented as follows:

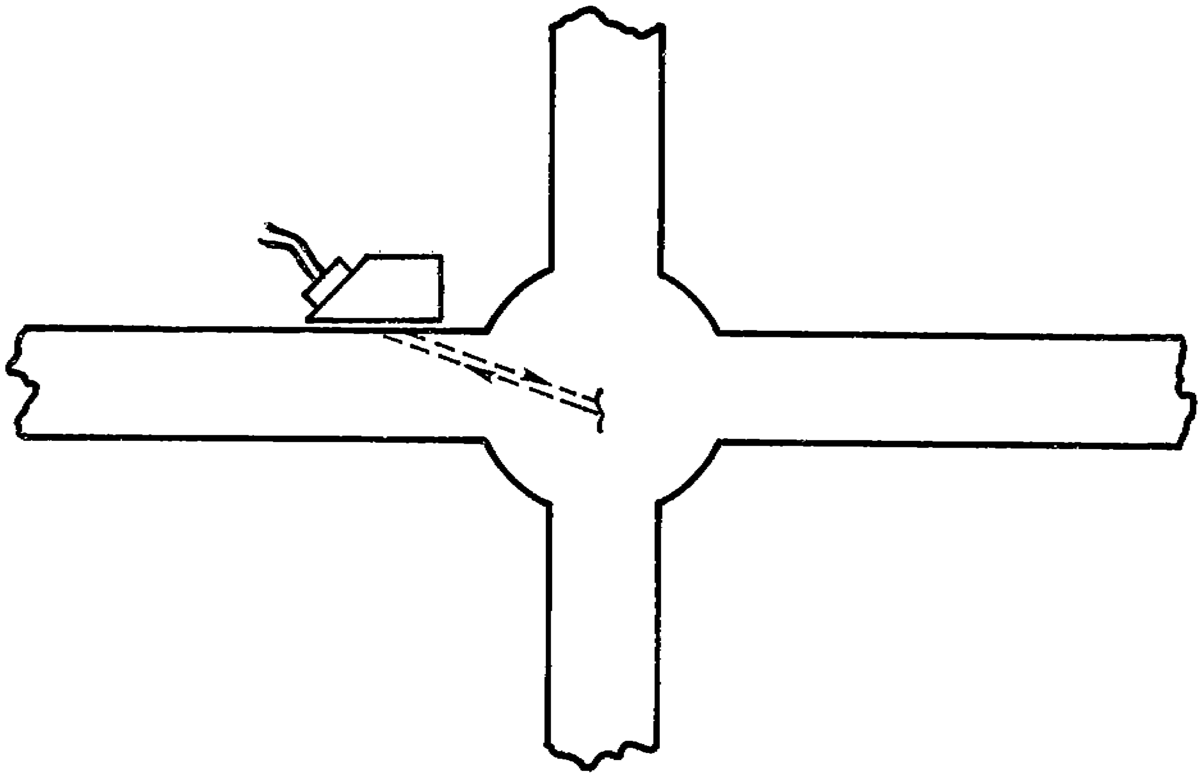


FIG. 15 ULTRASONIC PROCEDURE FOR INSPECTING AN "X" JOINT WELD

Joint Preparation	Defect	Method of Inspection
	Unacceptable weld profile	Visual, weld gauge
	Cracks	Magnetic particle, radiography
	Slag	Radiography
	Porosity	Radiography
	Lack of fusion	Radiography

Visual Inspection. Lap joints may be visually inspected for adequate throat, and the fillet can be examined to ascertain that convexity or concavity does not exceed specified limits, Figure 16A and 16B.

Magnetic Particle Inspection. The thickness of the lower or the upper member, whichever is greater, should be used in determining the required magnetizing current from Table I. Yokes as well as prods may be used.

Radiographic Inspection. Radiography of lap joints may be accomplished by positioning the cassette and directing the x-ray beam as shown in Figure 17A. Two penetrameters are used. This provides proof of satisfactory technique for the thickness range involved. Because different thicknesses are inherent to this joint design, film density variations are to be expected on the radiograph. Interpretation should be limited to those portions of the weld area which exhibit a film density of at least 2.0.

The radiation beam may also be directed at an angle as illustrated in Figure 17B. For this type inspection, an angle of 45^{o} is recommended. An average thickness is computed by multiplying the lower member base metal thickness by 1.4 and adding to this the weld throat thickness, Figure 17B. The penetrameter should be placed directly on the weld, perpendicular to the x-ray beam. The identification numerals can be placed on the thinner side.

The computed average thickness can be used with the graph of Figure 3 to select a suitable x-ray energy.

Ultrasonic Inspection. Lap joints are unsuited to ultrasonic inspection.

ACCEPTANCE CRITERIA

Specifications which require nondestructive testing should include the limits permissible for each weld discontinuity of interest. This section considers the more common weld discontinuities and procedures whereby they may be controlled in degree if desired.

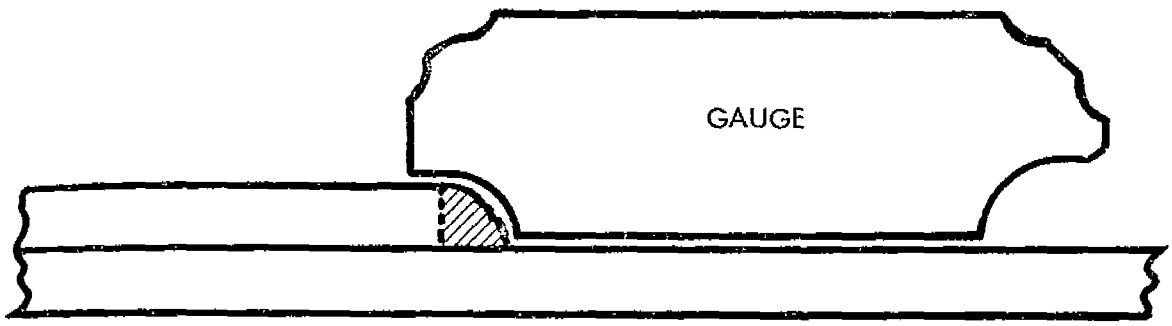


FIG. 16A CONVEXITY MEASUREMENT OF A LAP JOINT WELD

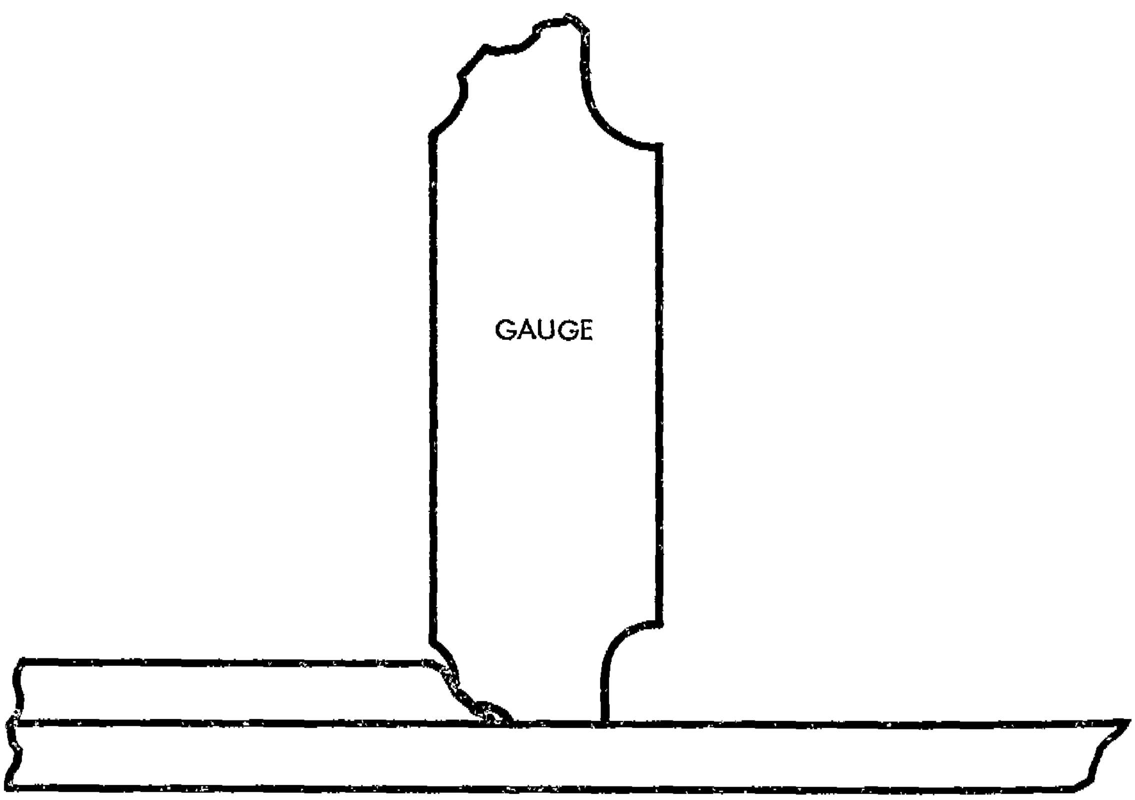


FIG. 16B CONCAVITY MEASUREMENT OF A LAP JOINT WELD

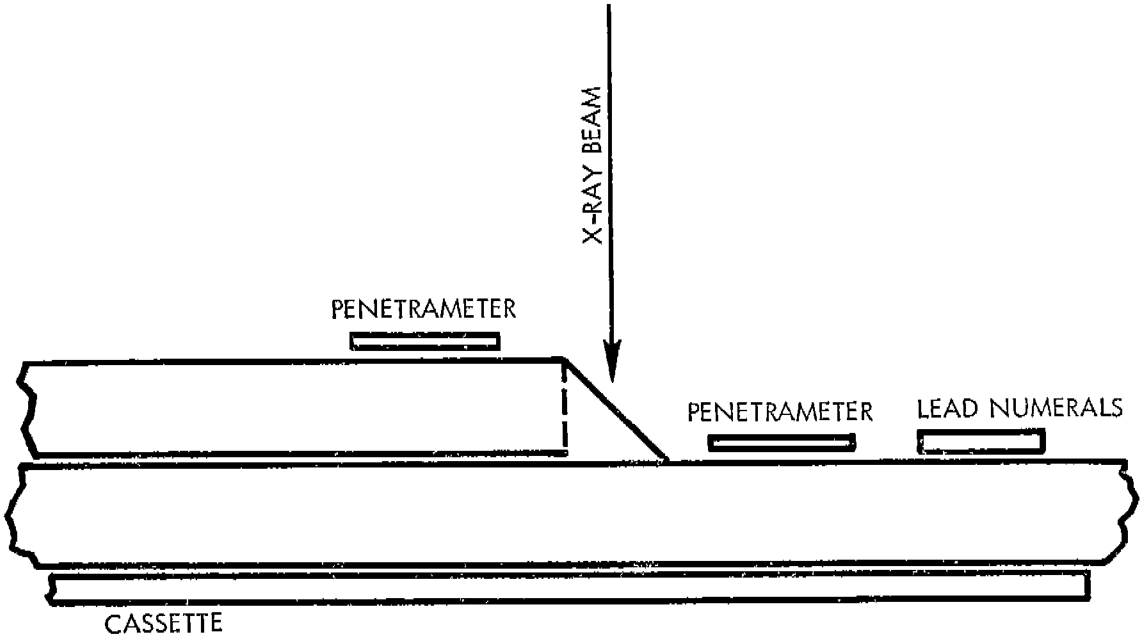


FIG. 17A ARRANGEMENT FOR PERFORMING RADIOGRAPHY OF A LAP JOINT WELD

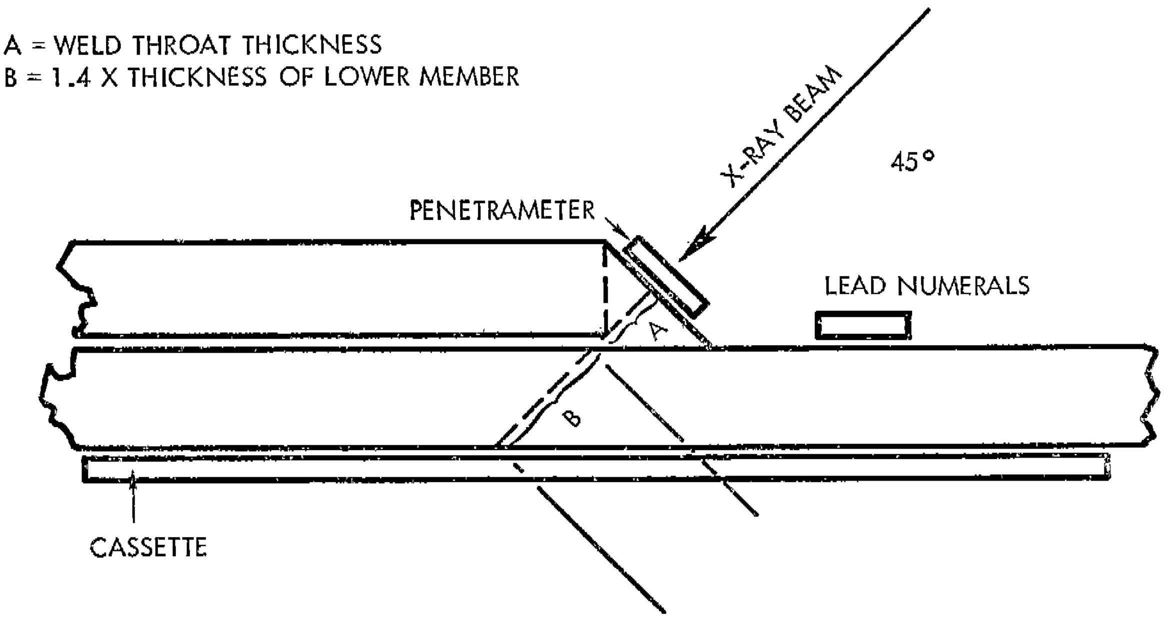
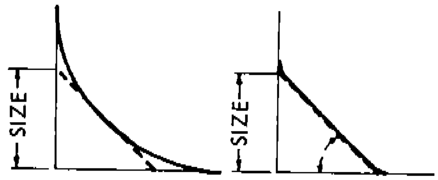


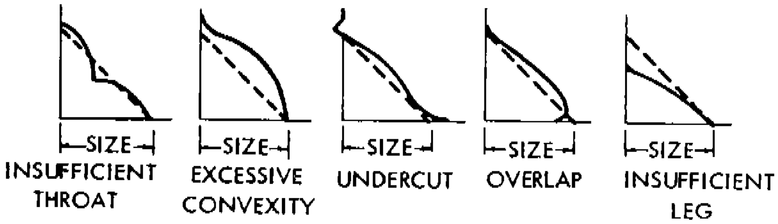
FIG. 17B ALTERNATE ARRANGEMENT FOR PERFORMING RADIOGRAPHY ON A LAP JOINT WELD

Visual Inspection.



DESIRABLE FILLET WELD PROFILES

The desirable fillet weld profiles are shown above. Excessive convexity, insufficient throat and insufficient leg can be controlled in degree by specifying the required size of the weld.



DEFECTIVE FILLET WELD PROFILES

Undercut and overlap can be limited in severity by specifying the maximum permissible depth and/or maximum length of indication.

Magnetic Particle Inspection. The magnetic particle method is used for crack detection. Specifications do not usually permit cracks in stress bearing welds.

Radiographic Inspection. The American Society for Testing and Materials has issued Reference Radiographs for Steel Welds, E-390-69. These consist of a series of five grade of increasing severity for each of the flaws listed below:

Fine Scattered Porosity
Coarse Scattered Porosity
Clustered Porosity
Slag Inclusions
Tungsten Inclusions
Lack of Fusion
Incomplete Penetration

Single illustrations are given of other types of weld discontinuities which may be detected by radiography but are not usually controlled in degree.

The reference radiographs are available for thickness of 0.030", 0.080", 0.187", 0.375". 0.750", 2.0", and 5.0". These reference radiographs are not in themselves specifications but may be used to control weld quality. This would be done by selecting illustrations of maximum permissible severity for each flaw type of interest, which would form a part of the contractual agreement.

Ultrasonic Inspection. The procedure for instrument calibration, set forth in Appendix I, provides a technique for weld inspection where the oscilloscope indications may be separated into three general categories. This is done by defining an amplitude disregard (DR) level at 40% of full screen height and an amplitude reject (AR) level at 80% of full screen height.

With the instrument properly calibrated, the planar type flaws such as cracks or lack of fusion typically produce a high-amplitude signal in excess of the "AR" level. Indications less than the "DR" level are not usually attributed to serious flaws are disregarded. Signals between the "AR" and "DR" levels are usually related to non-planar weld discontinuities such as slag.

In addition to the requirement for proper instrument calibration, specifications involving ultrasonic inspection should consider the maximum length for flaws above the "AR" level and for those greater than the "DR" but less than the "AR" level. Weld quality may also by controlled by specifying the permissible cumulative flaw length or by limiting the distance between flaws.

Typical weld flaws and their signal amplitudes in relation to the AR and DR levels are presented in the schematic of Figure 18.

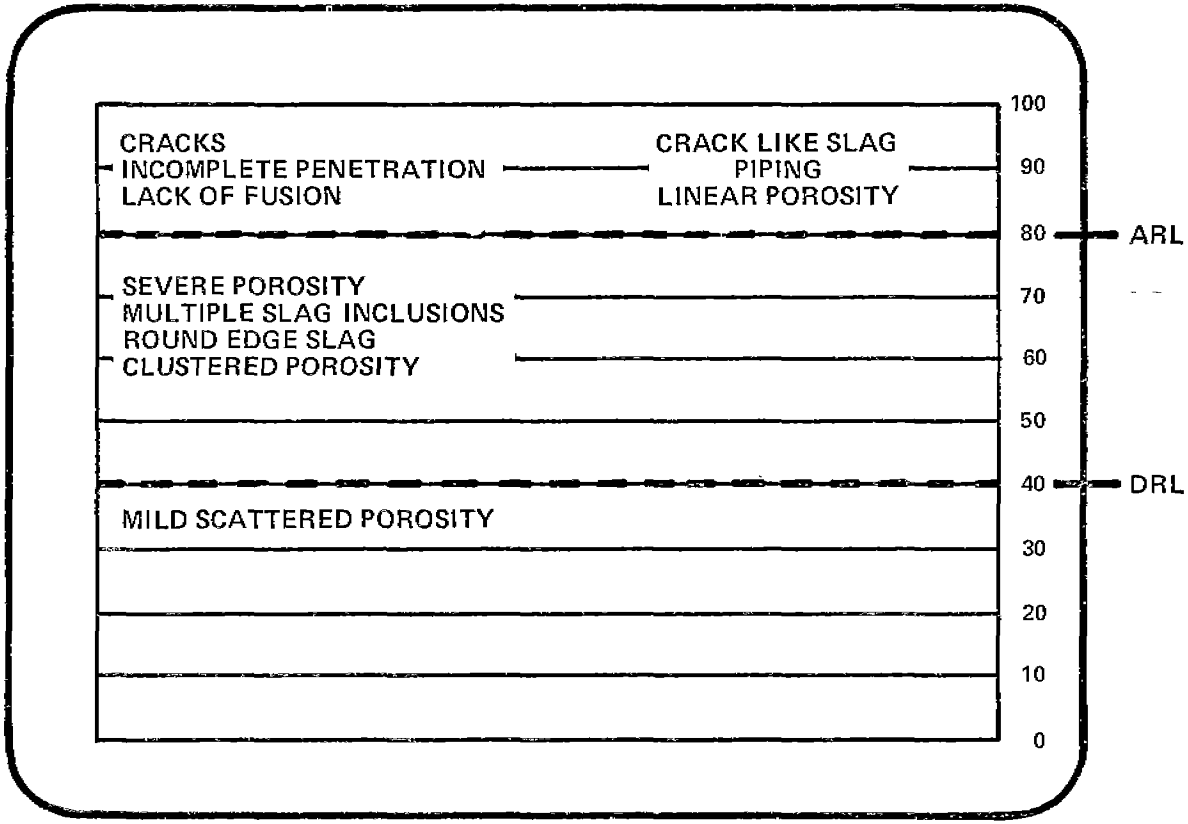


FIG. 18 TYPICAL ULTRASONIC SIGNAL AMPLITUDES PRODUCED BY VARIOUS DEFECTS

APPENDIX A

SSC-213

A GUIDE FOR ULTRASONIC TESTING AND EVALUATION OF WELD FLAWS

SCOPE

This document presents procedures and acceptance limits for contact ultrasonic inspection of steel butt welds in the thickness range of 1/4 to 2 inches. The acceptance limits described in the following sections are compatible with those set forth in SSC-177, "Guide for Interpretation of Nondestructive Tests of Welds in Ship Hull Structures" for radiographic inspection and should therefore result in satisfactory ship welds. Occasions may arise where radiographic inspection could provide additional information.

TEST METHOD

General - The procedures given apply to the contact ultrasonic inspection of butt welds. Weld inspection is accomplished by introducing shear waves into a plate at a selected angle and manipulating the transducer so as to scan the entire weld, Fig. A-1.

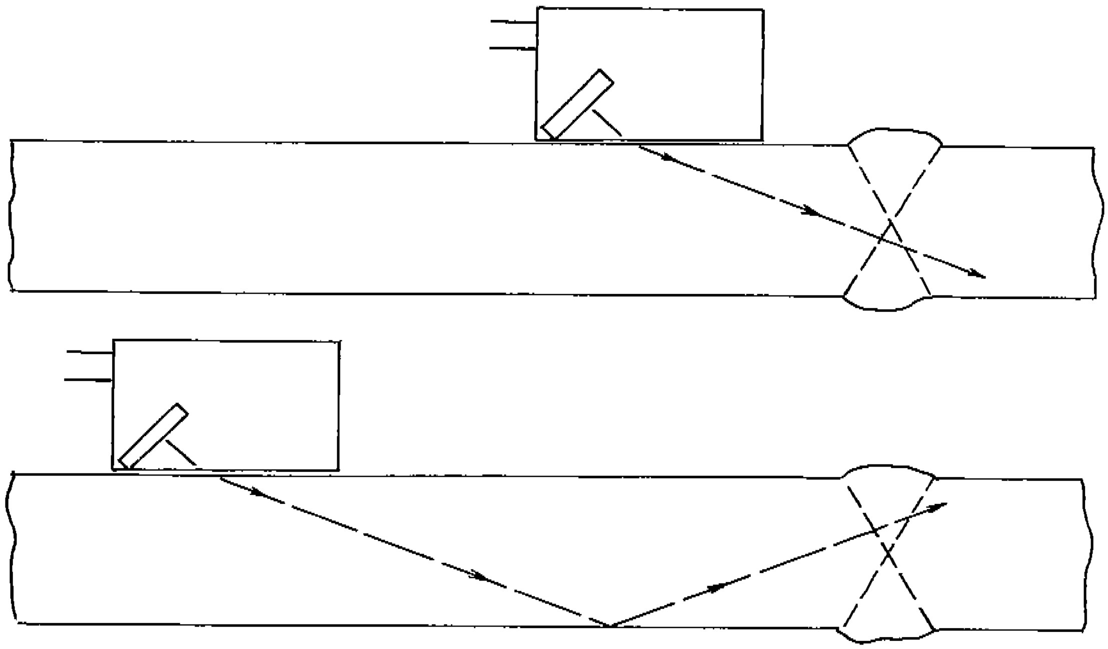


FIG. A-1. TECHNIQUE FOR INSPECTING BUTT WELDS WITH SHEAR WAVES

Equipment - The ultrasonic instrument shall be of the pulse-echo type with an A-scan presentation. It shall be capable of generating, receiving and displaying screen pulses from 1 to 5 MHz on the cathode ray tube. The instrument shall have a circuitry to provide a continuously increasing amplification with respect to time or distance of travel. A calibrated decibel attenuator control is recommended. Battery powered equipment must contain an alarm to signal battery depletion prior to instrument shut-off due to battery exhaustion.

Transducers - The maximum dimension (manufacturers' specifications) of the transducer active element shall not exceed one inch. A ratio of 2:1 width to height of the active element is recommended. A nominal test frequency of 2.25 MHz is recommended.

Selection of Probes - The primary consideration for selecting a probe shall be the thickness of the plate. The following shear wave angles are recommended:

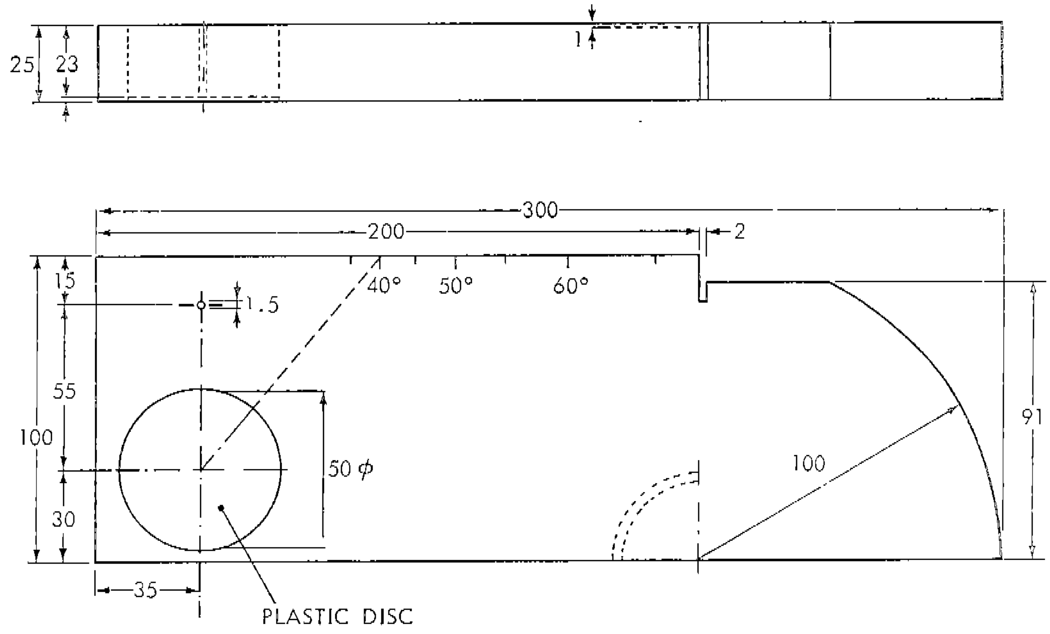
70° for plate thicknesses 1/4" to 1/2"

60° or 70° for plate thicknesses 1/2" to 1-1/2"

45° or 60° for plate thicknesses 1-1/2" to 2-1/2".

The transducer angle should be checked periodically with the International Institute of Welding Test Block, Fig. A-2.

Couplant - A liquid such as glycerin diluted with alcohol or water and to which a wetting agent has been added is recommended for acoustic coupling between the transducer and the plate. Most oils are acceptable. For overhead work and for places of difficult access certain types of grease may



NOTE: ALL DIMENSIONS IN MILLIMETERS
1 INCH 25.4 MM

FIG. A-2. INTERNATIONAL INSTITUTE OF WELDING TEST BLOCK FOR ULTRASONIC CALIBRATION prove useful. Any couplant should be removed upon completion of the inspection.

Surface Preparation - The average plate as received from the mill has a surface that is smooth enough for ultrasonic inspection. Plate with loose scale, flaked paint, excess rust, or pitting will require grinding. After welding, the surface of the base metal where the probe is to be manipulated should be cleaned of weld splatter. If surface irregularities on the weld bead interfere with the ultrasonic test or cause difficulties in interpretation then the weld bead should be ground reasonably smooth.

Base Metal Inspection - Although the presence of laminations in the base metal may not be a basis for rejection, these reflectors may mask a part of the weld from the ultrasonic beam, Fig. A-3, or cause the operator to incorrectly locate a discontinuity, Fig. A-4. Laminations can be detected ultrasonically with a straight beam (longitudinal waves). When laminations are encountered, the inspection should be made from the other side of the weld.

PERSONNEL QUALIFICATION

Supplement C, Ultrasonic Testing Method, TC-1A Recommended Practice, American Society for Nondestructive Testing, shall apply. Ultrasonic testing may be carried out by a Level II operator or by a Level I operator under the direct supervision of a Level II operator.

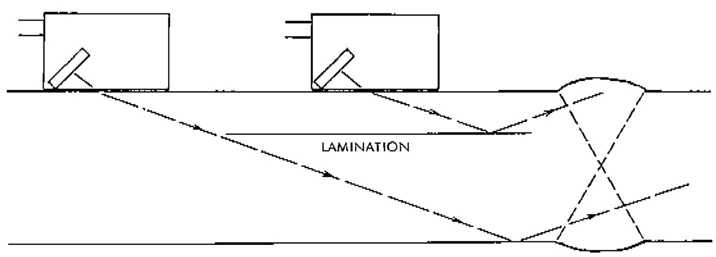


FIG. A-3. MASKING EFFECT OF A BASE METAL LAMINATION

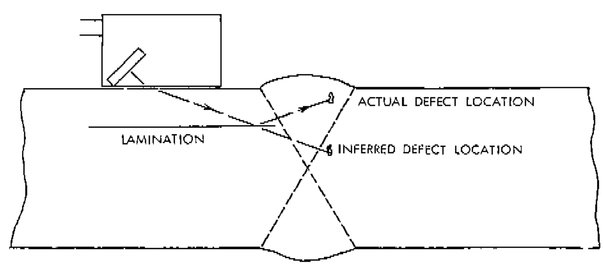


FIG. A-4. POSITION ERRORS INTRODUCED BY BASE METAL LAMINATION

CALIBRATION STANDARDS

A test block shall be prepared from material experimentally determined to be defect free and which is acoustically similar to the work material. This block should be 1-1/4" thick with a series of 1/16" diameter drilled holes spaced to provide path lengths equivalent to the longest and shortest path lengths to be used in the weld inspection. Intermediate distances should also be provided. The scanning surfaces should be approximately 250 RMS, prepared by the grinding method with the direction of grind parallel to the long dimension of the test block. Figure 5 illustrates an acceptable design.

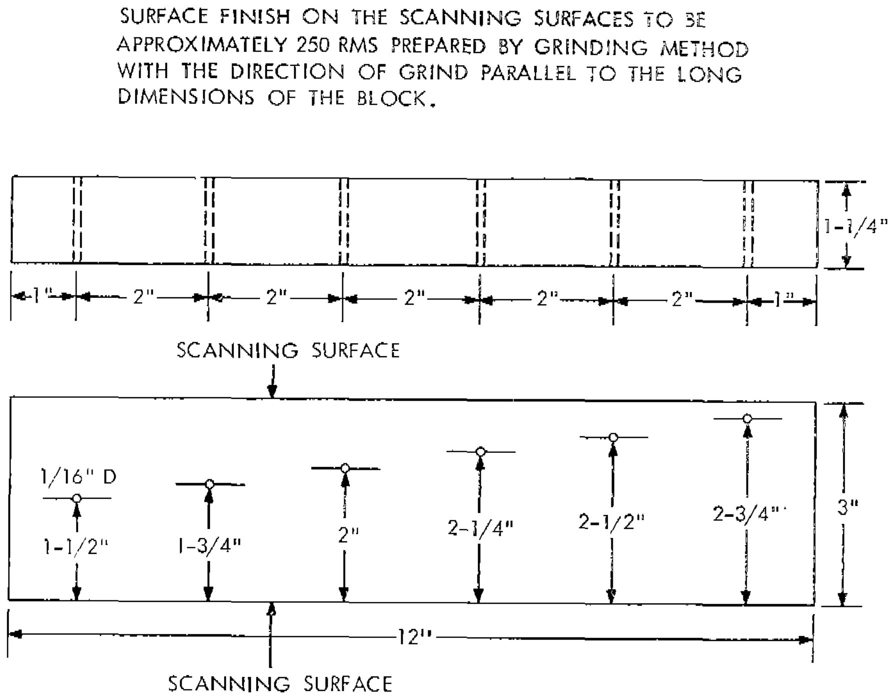


FIG. A-5. TYPICAL REFERENCE CALIBRATION STANDARD

INSTRUMENT CALIBRATION

Two levels of signal amplitude are defined in this Guide - ARL (Amplitude Reject Level) and DRL (Disregard Level). These two levels are established as follows:

The delay controls are used to position the initial pulse at the left of the viewing screen at a location marked zero on a reticule or screen scale. The instrument range controls can then be adjusted to display signals from the reference calibration drilled holes for the distances to be considered.

The distance amplitude correction controls are to be adjusted to compensate for signal loss due to distance of travel, i.e., the height of signals from all the reference drilled holes should be made equal.

When a decibel attenuator is available, the instrument gain control is to be adjusted to set the equalized signals from the reference reflectors at 40% of full screen height, Fig. A-6. The gain is then increased by 6 decibels. At this setting, the ARL is 6 decibels above the 40% line and the DRL (screen height below which indications are to be disregarded) shall be the 40% line, Fig. A-6.

When a decibel attenuator is not available, the instrument gain control is to be adjusted to set the equalized signals from the reference reflectors at 80% of full screen height, Fig. A-7. For this setting the 40% line shall be the DRL and the 80% line shall be the ARL, Fig. A-7.

In both of the above cases the calibration should be checked frequently.

WELD INSPECTION

Longitudinal defects are found by directing the sound beam normal to the length of the weld and moving the transducer back and forth, Fig. A-8, to scan the entire weld. Simultaneously, the transducer is oscillated through a small angle. The back and forth motions should be repeated at intervals which do not exceed 80% of the width of the transducer as the probe is moved along the weld.

Transverse defects are detected as follows:

a. For welds ground smooth the transducer is placed on top of the weld and moved along its length, Fig. A-9.

b. For welds not ground smooth the transducer is placed alongside and not quite parallel to the weld and moved along the length, Fig. A-10.

The entire weld and heat affected zone should be scanned. The weld should be inspected from both sides of one surface.

DISCONTINUITY LENGTH DETERMINATIONS

When discontinuities are detected, the sound beam should be directed so as to maximize the signal amplitude. The transducer is then moved parallel to the discontinuity and away from the position of maximum signal amplitude. The extremity of the discontinuity is defined as the point at which the signal amplitude drops to one-half of the peak value. This point is marked using the center line of the wedge as an index. In a similar manner, the other extremity is found and the distance between marks is defined as the length of the discontinuity. The minimum recordable length of a discontinuity shall be 1/8".

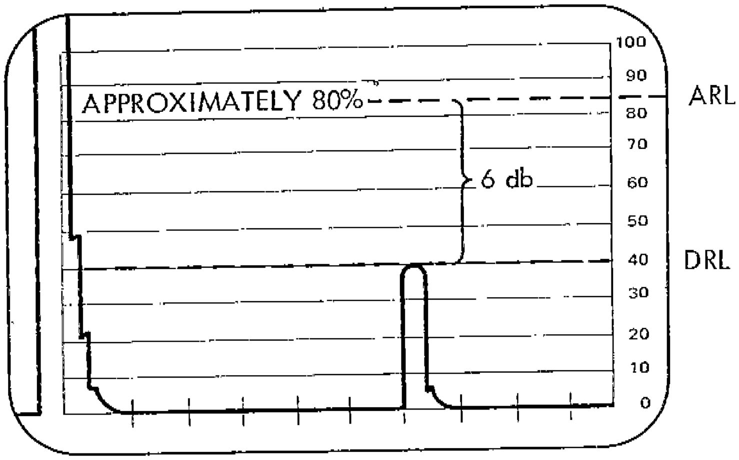


FIG. A-6. TYPICAL VIEWING SCREEN CALIBRATION
FOR INSTRUMENTS WITH DECIBEL ATTENUATION CONTROLS

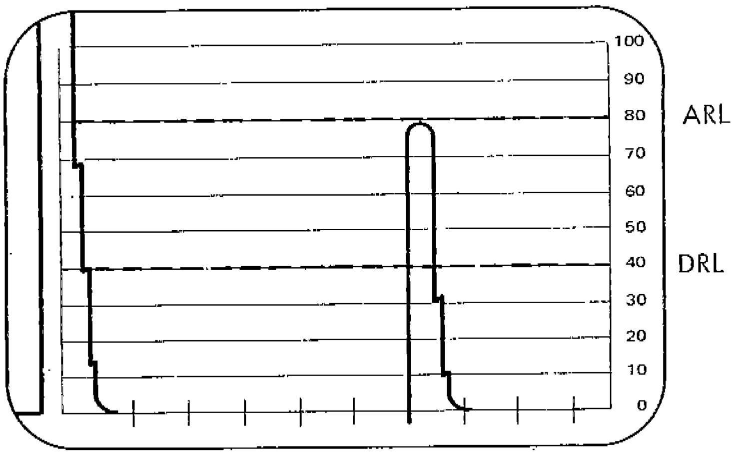


FIG. A-7. TYPICAL VIEWING SCREEN CALIBRATION
FOR INSTRUMENTS WITHOUT DECIBEL ATTENUATION CONTROLS

NOTE: CALIBRATION IS PERFORMED WITH THE REFLECTION OBTAINED FROM THE WALL OF A 1/16" DRILLED HOLE USING DISTANCE-AMPLITUDE CORRECTIONS.

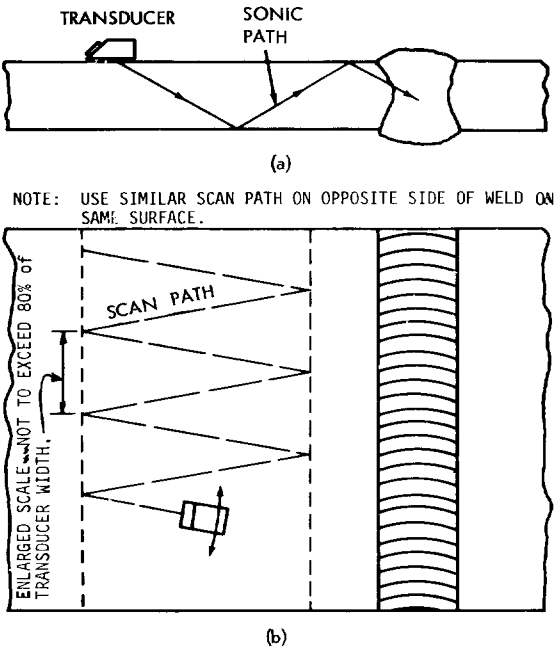


FIG. A-8. TECHNIQUE FOR INSPECTING BUTT WELDS WITH SHEAR WAVES

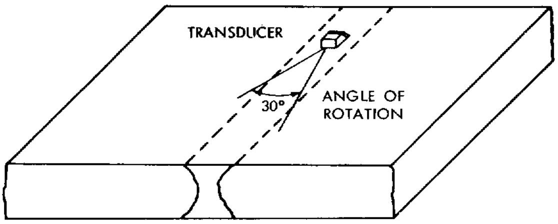


FIG. A-9. SUPPLEMENTARY TECHNIQUE FOR INSPECTING BUTT WELDS WHEN THE WELD BEAD IS GROUND FLUSH

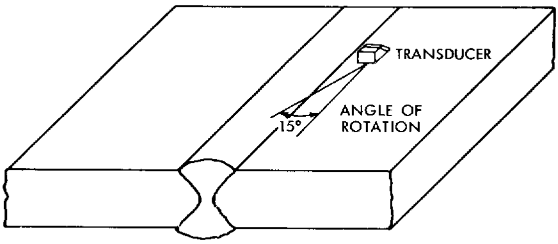


FIG. A-10. SUPPLEMENTARY TECHNIQUE FOR INSPECTING BUTT WELDS WHEN THE WELD BEAD IS NOT GROUND FLUSH

DISCONTINUITY EVALUATION

Discontinuities which do not produce signal amplitudes equal to or greater than the DRL, Fig. A-11, shall be disregarded.

Discontinuities which cause signal amplitudes equal to or greater than the DRL but less than the ARL, Fig. A-12, require a length determination and are evaluated as follows:

a. Defects with length greater than ½ T where T is the thickness of the plate are unacceptable.

b. For multiple indications, where L is the length of the larger discontinuity, if the separation distance is less than 6L then the sum of the adjacent lengths shall not exceed ½ T. If the separation distance is more than 6L then the cumulative length in any 6" length of weld shall not exceed the plate thickness.

Any discontinuity which produces signal amplitudes in excess of the ARL, Fig. A-13, is unacceptable.

When base metals of different thicknesses are welded together the thickness of the thinner member shall be used in determinations of acceptable limits of discontinuities.

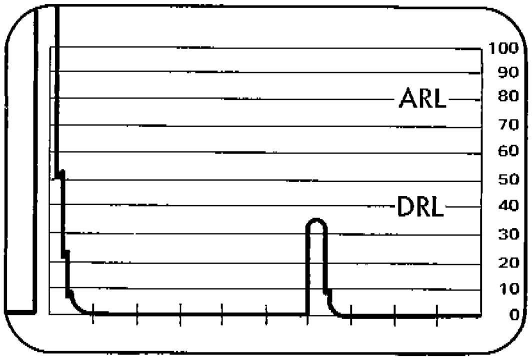
With the ultrasonic instrument calibrated in accordance with the procedures set forth in this Guide, usual signal amplitudes for specific type weld defects in relation to the ARL and DRL are illustrated in Fig. A-14.

When rejectable conditions are encountered, radiography may be useful in determining the nature and extent of the discontinuity.

RECORD OF INSPECTION

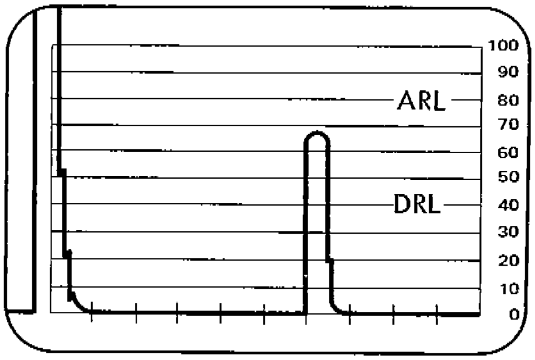
The record of each weld inspection should include:

1. Operator's identity
2. Date
3. Instrument identity
4. Transducer type, size, frequency and angle
5. Identification of test object
6. Location of the weld
7. Type of material
8. Thickness of base plate
9. Type of joint and configuration
10. Condition of the weld bead
11. Couplant
12. Flaw data
13. Inspection coverage, including reference points.



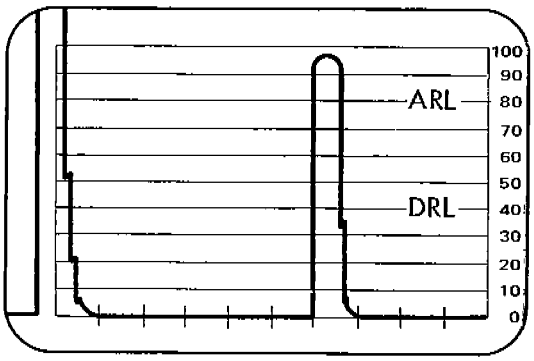
INDICATIONS BELOW THE DRL LEVEL ARE TO BE DISREGARDED

FIG. A-11. TYPICAL EXAMPLE OF ULTRASONIC INDICATIONS BELOW THE DRL.



INDICATIONS EQUAL TO OR GREATER THAN THE DRL LEVEL BUT LESS THAN THE ARL LEVEL REQUIRE A DETERMI-NATION OF DEFECT LENGTH AND SEPARATION DISTANCE

FIG. A-12. TYPICAL EXAMPLE OF ULTRASONIC INDICATIONS BELOW THE DRL BUT LESS THAN THE ARL



WELDS WHICH PRODUCE INDICATIONS EQUAL TO OR GREATER THAN THE ARL LEVEL ARE REJECTABLE

FIG. A-13. TYPICAL EXAMPLE OF ULTRASONIC INDICATIONS ABOVE THE ARL

WITH THE ULTRASONIC INSTRUMENT CALIBRATED IN ACCORDANCE WITH THE PROCEDURES SET FORTH IN THIS GUIDE, WELD DEFECTS OF THE TYPES LISTED WILL USUALLY PRODUCE SIGNAL AMPLITUDES IN RELATION TO THE ARL AND DRL LEVELS AS SHOWN:

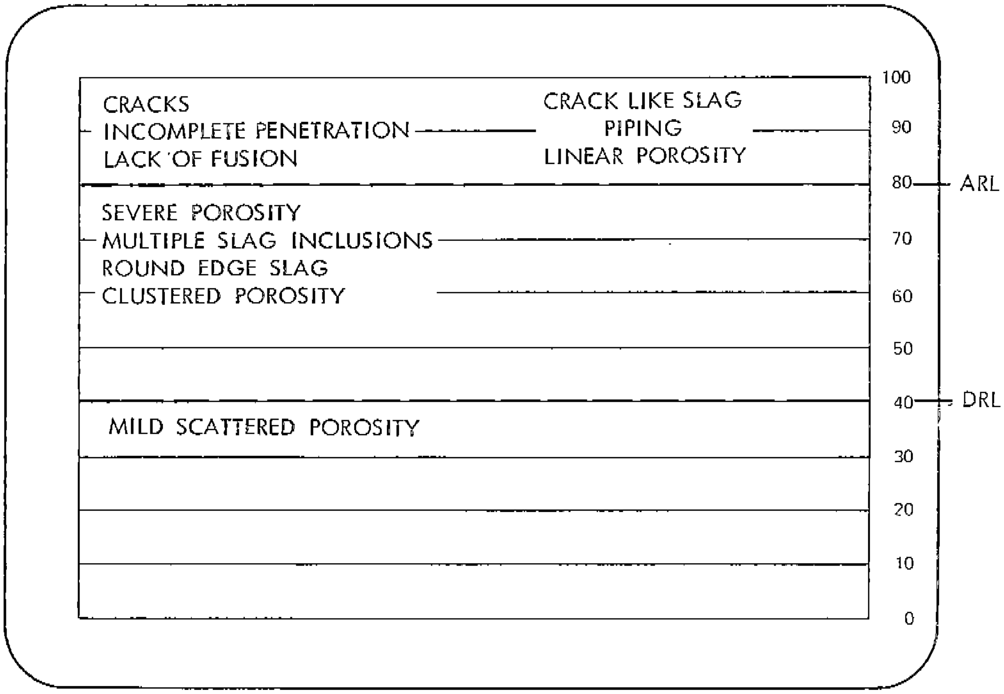


FIG. A-14. TYPICAL ULTRASONIC SIGNAL AMPLITUDES PRODUCED BY VARIOUS DEFECTS

A-Scan - A method of data presentation on a cathode ray tube utilizing a horizontal base line which indicates elapsed time when reading from left to right. A vertical deflection from the base line indicates reflected signal amplitudes.

Acoustically Similar - The same type of material as that to be inspected, or another material which has been experimentally proven to have acoustic velocity within ±3% and an attenuation for shear waves at the frequency to be used within ±0.25 dB/inch of the material to be inspected.

Active Element - The piezo-electrical material in the ultrasonic probe.

ARL (Amplitude Reject Level - The horizontal level on the cathode ray tube established by calibration. After calibration the ARL is 80% full screen height or 6 dB above the 40% line if a decibel attenuator is available.

Decibel - A logarithmic function of the ratio of two values. In ultrasonics the two values are the signal amplitude and a reference amplitude.

Decibel Attenuator - A gain control calibrated in decibels.

Delay Controls - An electronic means of horizontally shifting the pattern obtained on the cathode ray tube.

DRL (Disregard Level) - The horizontal level on the cathode ray tube established by calibration. After calibration the DRL is 40% of full screen height.

Frequency - The number of cycles in a unit of time. In ultrasonics the frequency is usually expressed in Megahertz or MHz (million cycles per second).

Longitudinal Waves - A wave form in which the particle motion is essentially in the same direction as the wave propagation.

Megahertz (MHz) - A million cycles per second.

Pulse Echo - The sending of sound into a material in the form of spaced pulses and recording the length of time necessary for each pulse to travel through the medium and return to the source of energy.

RMS (Root Mean Square) - A type of average used in describing surface roughness.

Resulting Angle - The angle formed between the ultrasonic beam as it enters a medium of different characteristics than the one from which it came and a line drawn perpendicular to the interface between the two media.

Scanning Surface - The surface of the base metal where the ultrasonic probe is manipulated.

Shear Wave - A wave form in which the particle motion is perpendicular to the direction of wave travel.

Straight Beam - An ultrasonic technique which does not involve an angle. The wave form is longitudinal.

Transducer - A device for converting energy of one type into another. An ultrasonic transducer converts energy from electrical to mechanical and vice versa.

NOTES

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This report has been prepared in two parts: Part 1 is the guide for the nondestructive testing of non-butt welds in commercial ships. Part 2 documents the technical considerations involved in preparing that guide.

Procedures are presented for performing visual inspection, magnetic particle testing, radiography, ultrasonics, and penetrant testing on steel welds in the thickness range of

1/2" to 2 1/2". The basic weld joints considered are the corner joint, the Tee, "X", and the lap joint. A discussion is presented for each of the inspection methods whereby weld quality may be controlled in a meaningful way when there is a need to do so.

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