

SSC-177

**Guide for Interpretation
of
Non-Destructive Tests of Welds
in
Ship Hull Structures**

SHIP STRUCTURE COMMITTEE

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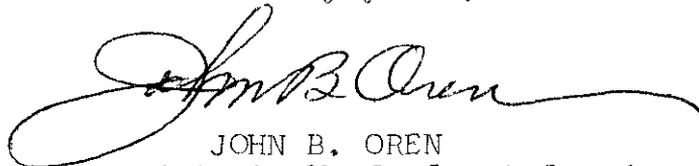
September 1966

Dear Sir:

In connection with its work of fostering research towards improving hull structures and making the results available to ship designers and ship-builders, the Ship Structure Committee has published Report SSC-177, Guide for Interpretation of Non-Destructive Tests of Welds in Ship Hull Structures. A copy is furnished herewith.

Although the authors of the report brought much experience to bear upon the problem and consulted with others well informed in the field, it is expected that some of a wider body of readers may disagree with some of the content and have recommendations as to improved presentation or other material that should be included. It will, therefore, be appreciated if after review of the publication, you will furnish to the Secretary of the Ship Structure Committee, any suggestions that you may have for its improvement.

Sincerely yours,



JOHN B. OREN
Rear Admiral, U. S. Coast Guard
Chairman

SSC-177

GUIDE FOR INTERPRETATION
OF
NON-DESTRUCTIVE TESTS OF WELDS
IN
SHIP HULL STRUCTURES

Prepared for the
SHIP STRUCTURE COMMITTEE

by the
Weld Flaw Evaluation Committee

National Academy of Sciences-- National Research Council

Washington, D. C.

National Academy of Sciences - National Research Council
September 1966

This is a report of work under
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The opinions and conclusions presented in this report are those of the Weld Flaw Evaluation Committee and not necessarily those of the Ship Structure Committee nor of the Department of the Navy.

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FOREWORD

At the present time the shipbuilding industry, as concerned with general cargo tanker and passenger ship construction, does not have a uniformly accepted procedure for examining and comparing the quality of welds in such ships. As an attempt to satisfy this need the accompanying "guide" has been prepared.

The Committee preparing this "guide" possesses broad experience in nondestructive testing. In addition, they reviewed currently available codes and Standards such as "Radiographic Standards for Welds" CG-115-1 January 2, 1965, "Radiographic Standards for Production and Repair Welds" (NAVShips 250-692-2), ASTM reference radiographs, those of The American Welding Society, and the ASME Boiler and Pressure Vessel Code.

The resulting "guide" has been developed by modifying some of the above codes for structures other than ship hulls as it was the general belief of the committee that a slightly higher level of some types of flaws such as slag inclusions could be tolerated in ship hull welds. Retention of the positive rejection principle for the potential failure initiating type flaws such as cracks, lack of penetration, etc., maintains the essential integrity of the weld without excessive demands that might adversely influence cost. Experience in the shipbuilding industry supports the belief that this "guide" will result in ship welds satisfactory in every respect.

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GUIDE FOR INTERPRETATION OF
NON-DESTRUCTIVE TESTS OF WELDS IN SHIP HULL STRUCTURES

This document relates to welds in ship hulls of the general cargo, tanker and passenger class as differentiated from naval ships.

Visual

Interpretation Standards

Fillet and butt-type welds should be inspected visually for conformance to the requirements shown in Fig. 1 for size, convexity, concavity, undercut, overlap, leg, throat, and excessive weld irregularities.

Radiography*

Test Method

The procedures and guides set forth in this section are applicable to the radiographic inspection of groove welds in butt joints only, provided that the radiography is performed with qualified personnel and procedures.

Radiographs shall be made by either X-ray or gamma-ray and shall determine quantitatively the size of the defects having thickness equal to or greater than 2 per cent of the thickness of the thinner of the parts joined by the weld under examination.

**The radiographer shall be responsible for the protection and personnel monitoring of every man working with or near X-ray gamma radiation. This protection and monitoring shall comply with all pertinent A. E. C. and state health regulations. All radiographers should wear film badges and/or pocket dosimeters. A radiation survey meter should be on site at all times. The area in which radiography is performed should be properly roped off and posted as per A. E. C. , and state safety regulations.*

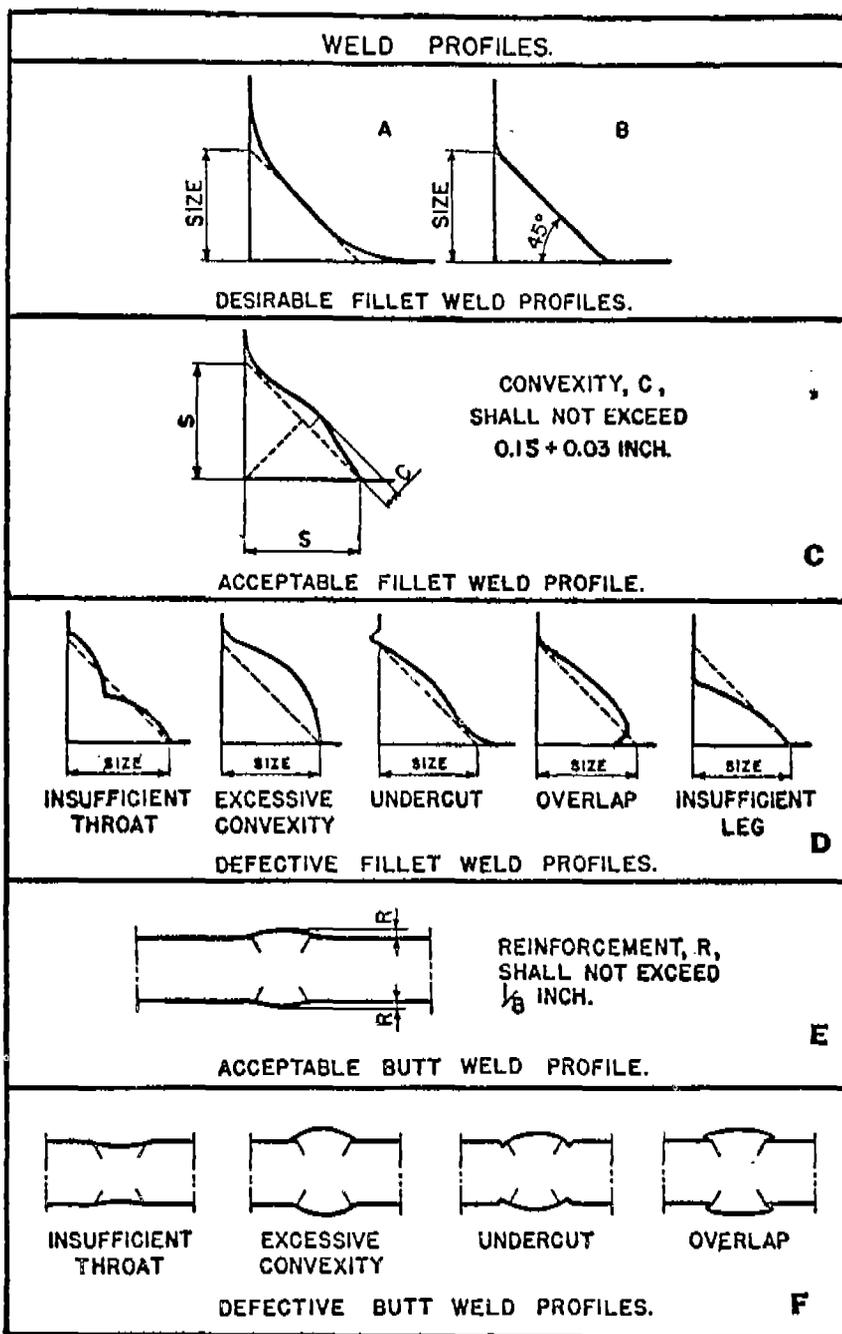


FIG. 1. Visual Inspection Standards.

Radiographs shall be clean, free of film processing defects, and shall have a density of not less than 1.5 as judged by density comparison strips or a densitometer. Any density above 1.5 is acceptable provided it can be interpreted by a sufficiently intense illuminator.

Where accessible surfaces to be radiographed have valleys and undercuts between weld beads, weld ripples or other surface irregularities, grinding the film side smooth is usually satisfactory so that the resulting radiographic contrast cannot mask or be confused with that of any defect.

Penetrameter

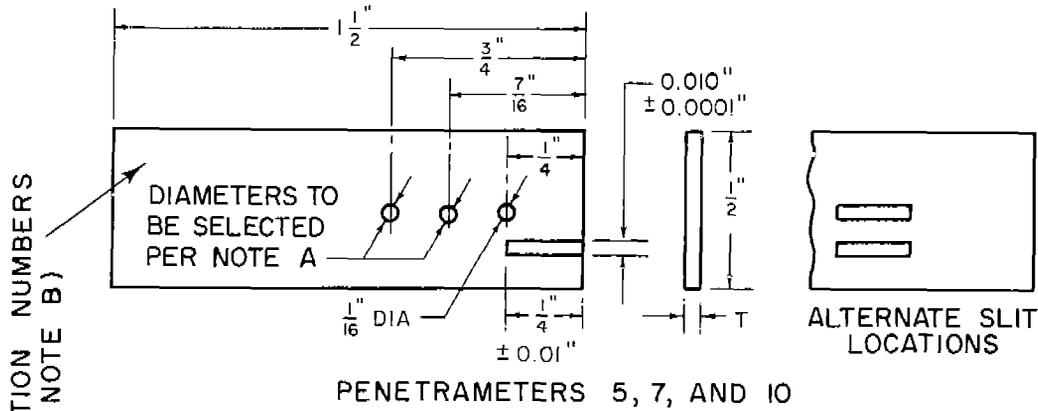
When weld reinforcement or backing is not removed, shims of radiographically similar material to the base material shall be placed under the penetrameter so that the total thickness of steel between the penetrameter and the film is at least equal to the average thickness of the weld, measured through its reinforcement and backing, if any is used. The outline of the shim should be visible on the film.

As a check on the radiographic technique employed, penetrameters, as described in Fig. 2, should be used in the following manner to determine whether the requirements of sensitivity are met. The smallest hole in the penetrameter should be distinguishable on the radiograph.

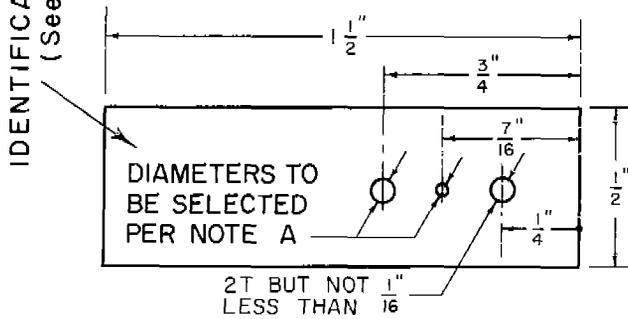
At least one penetrameter should be used for each exposure. It should be placed on the side of the base material nearest the radiation source so that it will appear near one end of the film but not on the weld in the area to be interpreted.

The material of the penetrameter and shim should be substantially the same as that of the plate under examination.

The thickness of the penetrameter should be in accordance with Fig. 2 based on the weld thickness of the thinner plate being radiographed.



PENETRAMEters 5, 7, AND 10



PENETRAMEters 12 - 50 INCL.

Note A:

The diameter of the remaining two holes shall be selected by the manufacturer; they will ordinarily be equal to three (3T) and four times (4T) the penetrameter thickness but they need not be smaller than 1/16 inch; but smaller holes are permitted. The holes shall be true and normal to the surface and not chamfered.

Note B:

Each penetrameter shall carry numbers at least three thirty-second of an inch high which identify the material of which it is made and indicate the thickness of plate to two significant figures for which it may be used.

Note C:

For penetrameters of 0.005 in. to 0.020 in. thickness, inclusive, the thickness tolerance is plus or minus .001 in. For penetrameters from 0.025 in. to 0.050 in. thickness, inclusive, the thickness tolerance is plus or minus 0.025 in.

<u>WELD THICKNESS RANGE</u>	<u>THICKNESS OF PENETRAMEter</u>	<u>DESIGNATION ON PENETRAMEter</u>
Up to $\frac{1}{4}$ inch inclusive	0.005 in.	5
Over $\frac{1}{4}$ in. thru $\frac{3}{8}$ in.	0.0075 in.	7
Over $\frac{3}{8}$ in. thru $\frac{1}{2}$ in.	0.010 in.	10
Over $\frac{1}{2}$ in thru $\frac{5}{8}$ in.	0.0125 in.	12
Over $\frac{5}{8}$ in. thru $\frac{3}{4}$ in.	0.015 in.	15
Over $\frac{3}{4}$ in. thru $\frac{7}{8}$ in.	0.0175 in.	17
Over $\frac{7}{8}$ in. thru 1 in.	0.020 in.	20
Over 1 in. thru $1\frac{1}{4}$ in.	0.025 in.	25
Over $1\frac{1}{4}$ in. thru $1\frac{1}{2}$ in.	0.030 in.	30
Over $1\frac{1}{2}$ in thru 2 in.	0.035 in.	35
Over 2 in. thru $2\frac{1}{2}$ in.	0.040 in.	40
Over $2\frac{1}{2}$ in. thru 3 in.	0.045 in.	45
Over 3 in. thru 4 in.	0.050 in.	50

FIG. 2. Penetrameter Requirements.

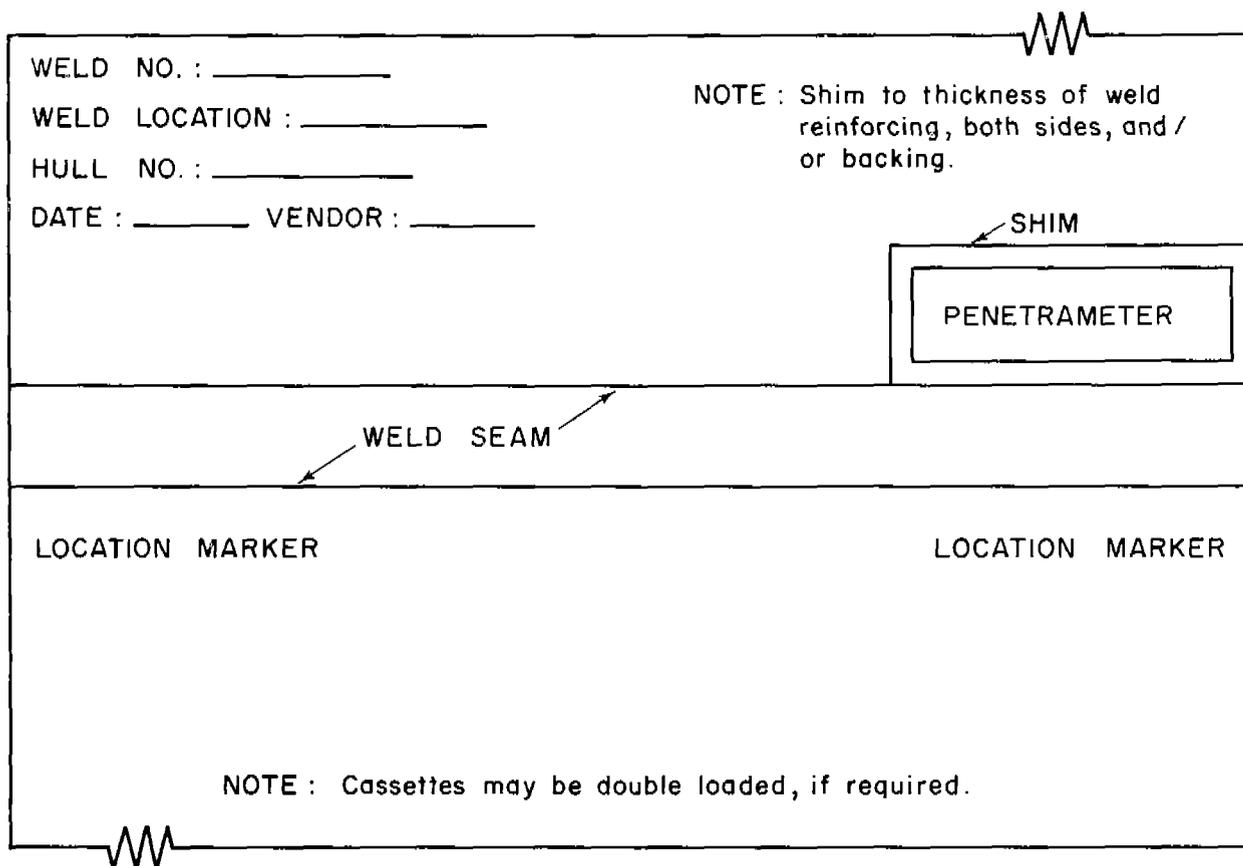


FIG. 3. Radiographic Film with Markings.

Film location markers, the image of which will appear on the film, should be placed adjacent to the weld and their locations shall be accurately marked on the base metal so that a defect appearing on the radiograph may be accurately located for repair if necessary before final acceptance. Identification of each film should be essentially as shown in Fig. 3.

All production radiographs showing defects should be compared directly with the weld when doubt exists as to whether the defect in question is a result of surface imperfections or sub-surface defects.

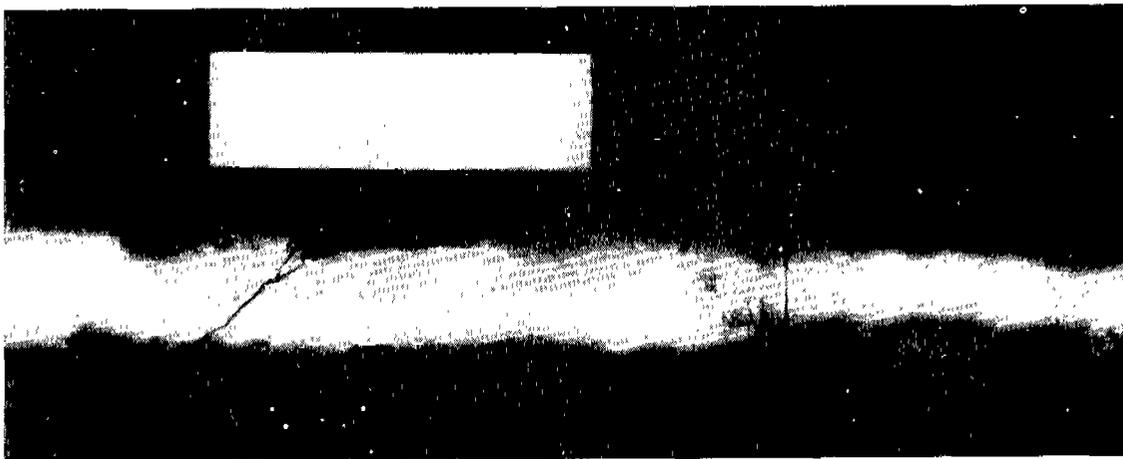


FIG. 4. Radiographic Print of a Crack.

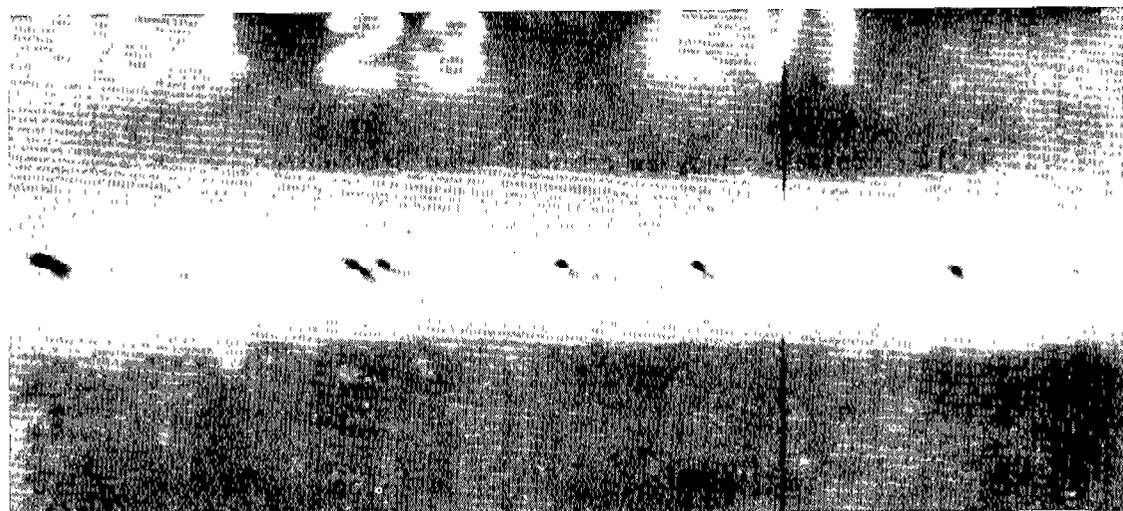


FIG. 5. Radiographic Print of Piping.

Interpretation Standards

It is not the object of this document to designate the location or extent of the inspection on a ship's hull but rather to provide guides for the interpretation of such radiographs by qualified personnel. Prints of radiographs showing the several types of typical weld defects are included.

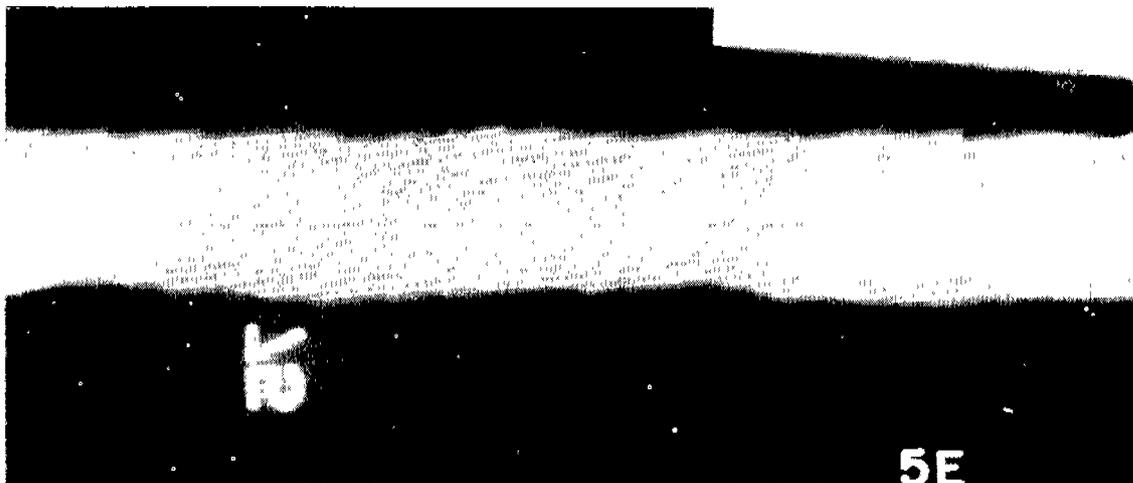


FIG. 6. Radiographic Print of Incomplete Penetration.

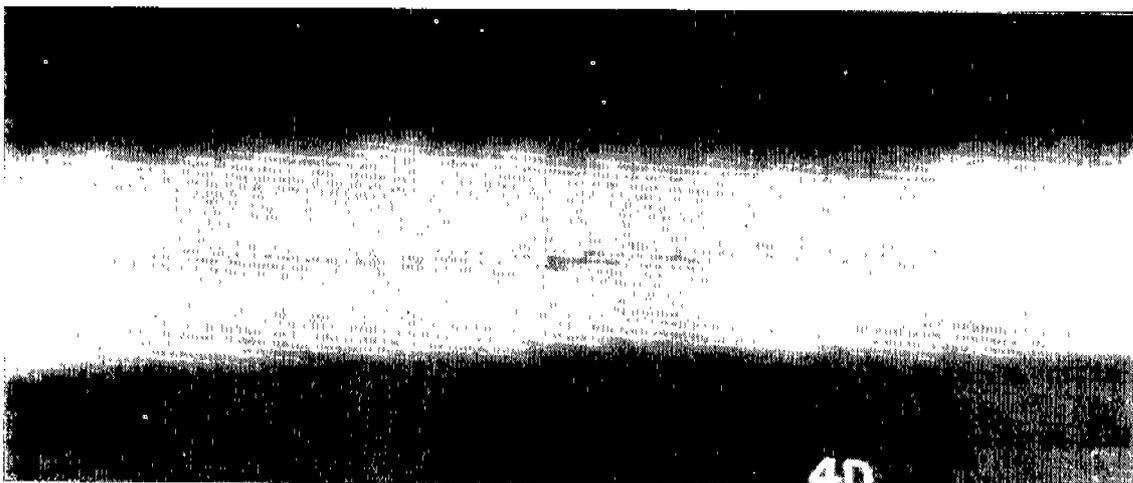


FIG. 7. Radiographic Print of Lack of Fusion.

1. Welds which contain cracks are unacceptable.
(Fig. 4.)
2. Welds which contain piping are unacceptable.
(Fig. 5.)
3. Welds which contain incomplete penetration
(Fig. 6.) or lack of fusion (Fig. 7.) are
unacceptable.

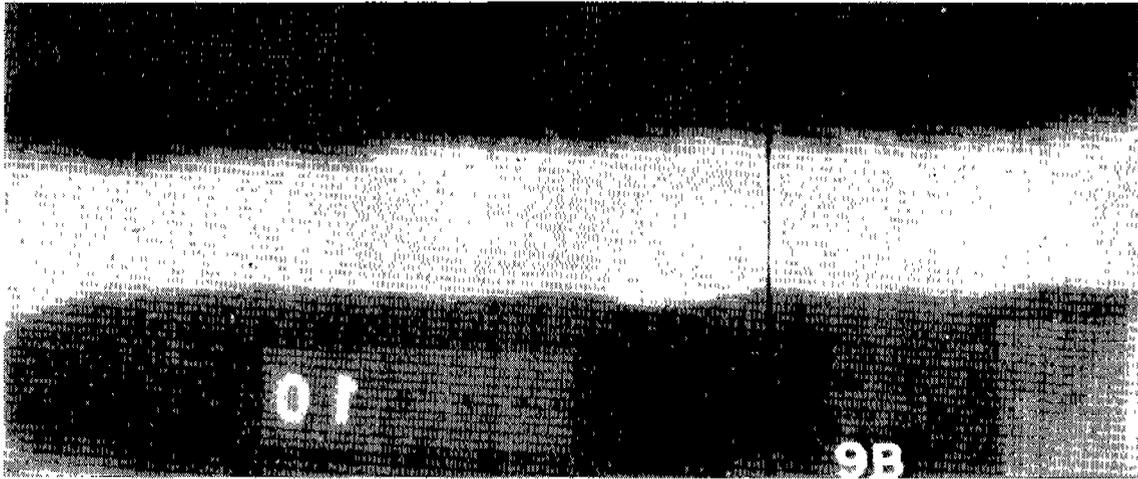


FIG. 8. Radiographic Print of Undercutting.

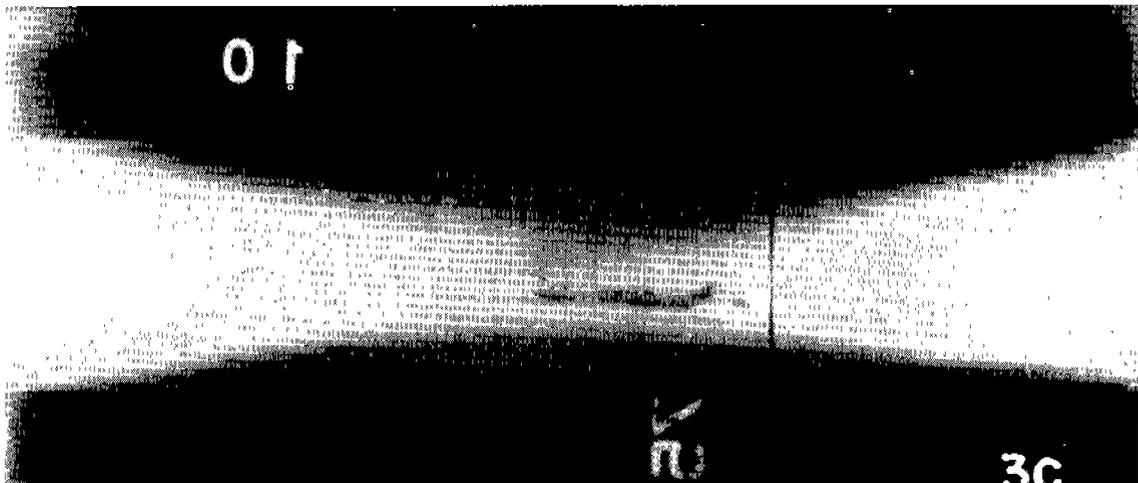


FIG. 9. Radiographic Print of Elongated Round-Edged Slag Inclusion.

4. Welds which show a V-shaped undercut more than 10% of material thickness or more than 1/32 in. in maximum depth and for a length greater than 1 in. are unacceptable. (Fig. 8.) Final decision on the degree of undercut should be made by visual inspection.



FIG. 10. Radiographic Print of Crack-Like Slag Inclusion.

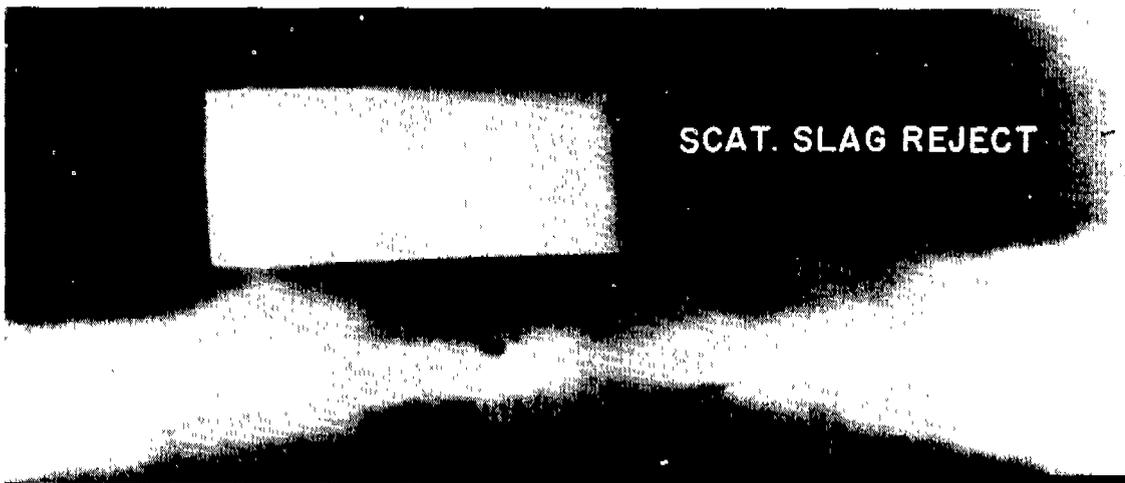


FIG. 11. Radiographic Print of Multiple Inclusions.

5. Welds which contain slag inclusions in excess of the limits outlined below are unacceptable.
 - a. Welds with elongated round-edged slag inclusions (Fig. 9.) greater in length than $1/2 T$, where T is the thickness of the plate.
 - b. Welds with elongated slag inclusions having crack-like indications as in Fig. 10.

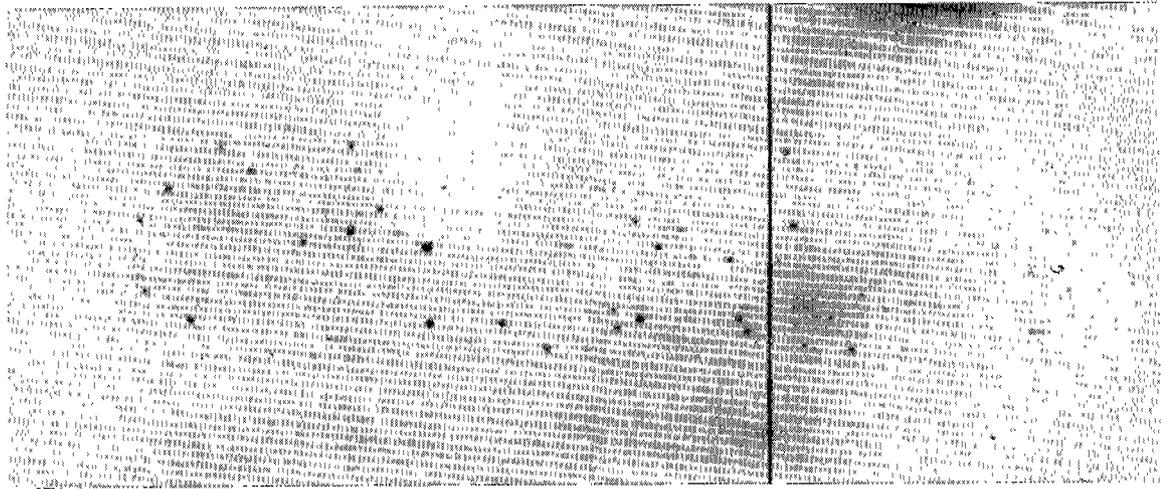


FIG. 12. Radiographic Print of Scattered Porosity illustrating acceptable distribution and number of voids.

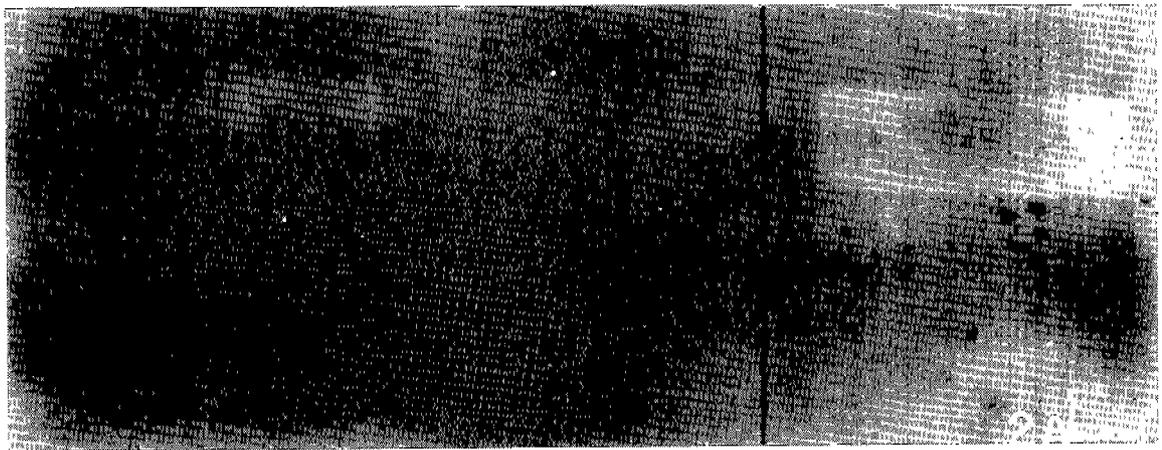


FIG. 13. Radiographic Print of Maximum Acceptable Clustered Porosity.

c. Welds with multiple inclusions (Fig. 11.) smaller than $1/2 T$, but whose cumulative length in any 6-in. length of weld exceeds the plate thickness or if the defects are separated by less than $6 L$ of acceptable weld metal, where L is the long dimension of the bigger inclusion.

6. Welds in which the radiographs show porosity should be judged unacceptable if they contain porosity in excess of the limits shown in Fig. 12 for scattered porosity and Fig. 13 for clustered porosity with either figure representing any portion of a thick-weld radiograph being represented by any portion of the figures. Any discontinuity whose major dimension is 1/8 in. and less and not judged to be a crack should be classed as porosity.

Magnetic Particle

Test Method

The magnetic particle inspection method is used for determining the presence of discontinuities at or near the surface of ferro-magnetic metals. It is applicable to fillet as well as butt-welds. The dry powder test method as provided in ASTM Standard E 109-63 is recommended. This test may be used for locating cracks at or near surfaces; for examing chipped or ground cavities prior to repair welding; and for laminations on edges of wrought plate. Supplemental tests may be necessary to identify particular types of indications.



FIG. 14. Longitudinal Crack Indicated by Magnetic-Particle Inspection.

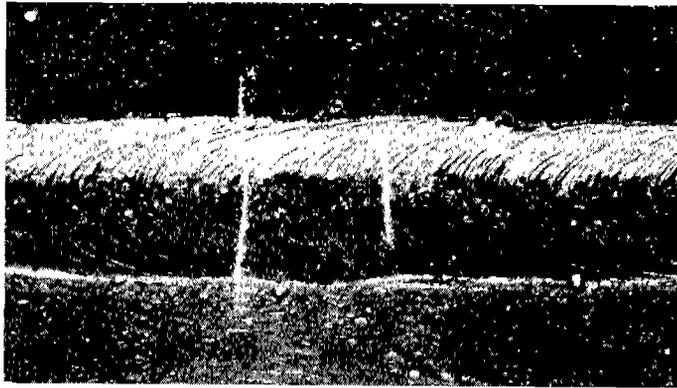


FIG. 15. *Transverse Crack Indicated by Magnetic-Particle Inspection.*

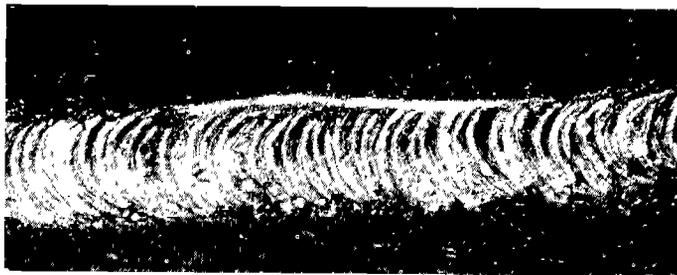


FIG. 16. *Fillet Weld Toe Crack Indicated by Magnetic-Particle Inspection.*



FIG. 17. *Root Crack Indicated by Magnetic-Particle Inspection.*

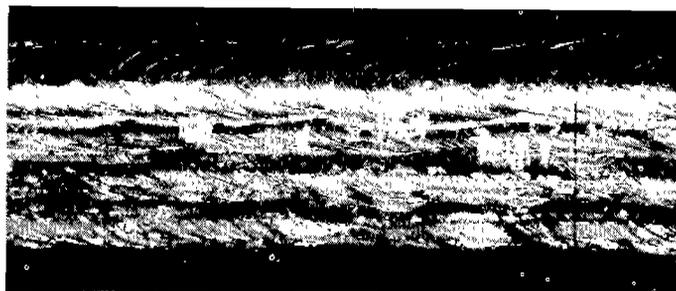


FIG. 18. *Slag or Porosity Indicated by Magnetic-Particle Inspection.*

Surfaces of parts should be dry and free of oil or any other material which might interfere with the formation or interpretation of magnetic particle patterns or indications.

The magnetic field should be induced and varied in such a manner as to insure detection of discontinuities having axes in any direction.

Interpretation Standards

Welds containing cracks are not acceptable. Closely spaced inline porosity, and/or slag may be interpreted for acceptance or rejection in accordance with the radiographic standards. Typical indications are shown in Figs. 14--18.

An indication of lack of penetration of fillet welds should be interpreted according to the contract weld design specifications for penetration.

Liquid Dye Penetrant

Test Method

The liquid penetrant test method as developed in ASTM Standard E-165-63 may be used for detecting the presence of discontinuities in ferrous or non-ferrous materials. Discontinuities not open to the surface will not appear, since penetration into an open defect is necessary before this method is operative.

Dye penetrant of the water washable type is recommended.

Surface of welds may be inspected without surface preparation or conditioning except as required to remove scale, and adhering materials. The cleaning method used should not close surface imperfections and interfere with the interpretation of results. As-welded surfaces, following the removal of slag should be considered suitable for liquid penetrant inspection without any grinding, provided the weld contour blends into the base metal without undercutting and the contour and surface finish of the weld is in accordance with applicable requirements.



FIG. 19. *Interbead and Marginal Indications by Liquid Penetrant.*



FIG. 20. *Porosity Indications by Liquid Penetrant.*



FIG. 21. *Deep Crack Indications by Liquid Penetrant.*



FIG. 22. *Crack and Slag Indications by Liquid Penetrant.*

The temperature of the penetrant and the part to be inspected should be maintained between 50 F and 100 F.

The test should be conducted by applying penetrant thoroughly, removing it, and developing it in accordance with the instructions from the penetrant manufacturer.

Interpretation Standards

Welds containing cracks are unacceptable. Welds containing closely spaced in-line porosity may be interpreted for acceptance or rejection in accordance with the radiographic standards. Typical indications are shown in Figs. 19 - 22.

Ultrasonic

In its present rapidly developing state as a manual inspection method, the generic process is recognized primarily for its flexibility and hence more ready applicability to primary exploration for weld quality. This holds specially for the types of welded assemblies encountered in ship hulls. Broader experimental use of this method is recommended so that, as a result of experience, bases can be developed for (1) completely adaptable equipment; (2) positive interpretation of test indications under diverse conditions. The process is therefore recommended as a survey method, its indications to be checked by radiography.

Where operator proficiency in ultrasonic detection has been demonstrated by comparing its results with radiography, ultrasonic inspection may be used in conjunction with radiography. Evaluation of ultrasonic indications shall be based on a correlation with radiographic acceptance standards.

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13. ABSTRACT A survey was made of various Codes and Standards applicable to the interpretation of radiographs of welds and the Guide has been developed for application to welds in ship hull structures of the general cargo, tanker and passenger class as differentiated from naval ships. The Guide exhibits typical X-ray and other non-destructive test results of several classes of defects with suitable text to delineate the maximum size and/or distribution that would be recommended as acceptable for ship hulls.			

14.	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
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