MIL-STD-1894A
17 October 1986
SUPERSEDING
MIL-STD-1894(AT)
26 June 1984

MILITARY STANDARD

RADIOGRAPHIC REFERENCE STANDARDS AND RADIOGRAPHIC PROCEDURES FOR PARTIAL-PENETRATION STEEL WELDS

AMSC N/A
AREA NDTI

DEPARTMENT OF DEFENSE
Washington, DC 20301

Radiographic Reference Standards and Radiographic Procedures
for partial-penetration Steel Welds

MIL-STD-1894

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Tank–Automotive Command, ATTN: AMSTA-GDS, Warren, MI 48397-5000, by using the self–addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

FOREWORD

This document contains selected radiographs illustrating various types and degrees of discontinuities occurring in partial-penetration steel welds. It also contains instructional data concerning radiographic inspection of this type of weldment.

It is intended that this document provide the following:

a. A weld discontinuity severity range for designers to select standards for acceptance inspection.
b. Reference standards for acceptance personnel to evaluate the quality of production weldments.
c. Guide lines for radiographers to effectively accomplish radiographic examination of partial–penetration welds.

The reference standards included in this document were prepared by the U.S. Army Tank-Automotive Command under project authorization of the U.S. Army Materials Technology Laboratory.

CONTENTS

			Page(s)
Paragraph	1.	SCOPE	1
	1.1	Scope	1
	1.2	Classification	1
	2.	REFERENCED DOCUMENTS	2
	2.1	Issues	2
	2.2	Other publications	2
	2.3	Order of preference	3
	3.	DEFINITIONS	4
	3.1	Partial-penetration joint design	4
	3.2	Radiation angle	4
	3.3	Radiograph	4
	3*3.1	Radiographic inspection	4
	3.3.2	Discontinuity	4
	3.3.2.1	Unfused area	4
	3.3.3	Flaw	4
	3.4	Penetrameter/Image quality indicator	4
	3.5	Metallographic cross - sections	4
	3.6	Welding terms and definitions	4
	3.6.1	Shielded metal arc welding	4
	3.6.2	Gas metal arc welding	5
	3.6.3	Gas tungsten arc (GTAW)	5
	3.6.4	Submerged arc welding (SAW)	5
	4.	GENERAL REQUIREMENTS	6
	4.1	Radiographic inspection	6
	4.1.1	Radiographic frequency	6
	4.1.2	Radiation angle	6
	4.1.3	Penetrameter requirements	6
	4,2	Acceptance standards	6
	4.3	Discontinuity types	6
	4.4	Discontinuity grading	7
	5.	DETAILED REQUIREMENTS	8
	5.1	Application of reference standards	8
	5.1.1	Determination of acceptability	8
	5.1.2	Quality levels of inspection	8
	5.1.3	Rules 1, 2, and 3	8
	5.1.4	Single discontinuity	9
	5.1.5	Multiple discontinuities	9
	5.1.6	False indications	9
	5.2	Inspection records	9
	6.	NOTES	10
	6.1	Changes from previous issue	10
	6.2	Subject term (key word) listing	10

CONTENTS - Continued.

Page(s)

FIGURES

Figure(s) 1-3	Recommended radiation angle and film location for typical partial-penetration joints	11-13
4	Correct and incorrect radiographic procedure for joint design (A)	14
5-6	Reference standards for fine scattered porosity in steel welds	15-16
7-8	Reference standards for coarse scattered porosity in steel welds	17-18
9-10	Reference standards for linear porosity in steel welds.	19-20
11	Reference standards for clustered porosity in steel welds.	21
12-13	Reference standards for scattered slag inclusions in steel welds	22-23
14	Examples of incomplete penetration correlated with weld cross-sections in steel welds	24
15	Examples of lack of fusion correlated with weld cross-sections in steel welds	25

1. SCOPE

1.1 Scope. This standard provides standard reference radiographs and recommended radiographic inspection procedures for partial-penetration weldments in steel plate, casting, or forging, 1/2 to 2 inches (12.70 to 50.80 millimeter) thick.

1.2 Classification. The reference radiographs comprised in this standard are intended primarily for use on manual or machine arc welding with the gas metal arc, gas tungsten arc, and submerged arc welding processes.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards and handbooks. Unless otherwise specified, the following specifications, standards and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this standard to the extent specified herein.

STANDARDS
MILITARY

MIL-STD-410	- Nondestructive Testing Personnel Qualification and Certification.
MIL-STD-453	- Inspection, Radiographic.
MIL-STD-1941	- Metal Arc Welding of Homogeneous Armor.

(Note: Negatives of radiographs illustrated in this standard can be purchased through AMSTA-GDS. Requests should be addressed to US Army Tank-Automotive Command, ATTN: AMSTA-GDS, Warren, MI 48397-5000.)

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity o as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E142	– Controlling Quality of Radiographic Testing, Method for.
ASTM E340	- Standard Method for Macroetching Metals and Alloys.

(Application for copies should be addressed to American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA, 19103.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)/AMERICAN WELDING SOCIETY (AWS)

ANSI/AWS A3.0	- Standard Welding Terms and Definitions including Terms for Brazing, Soldering, Thermal Spraying and Thermal Cutting.

(Copies of the above publications may be obtained from the American Welding Society, Inc., 550 N. W. LeJeune Road, P.O. Box 351040, Miami. Florida 33135.)

(Nongovernment standards are generally available for reference from libraries. They are also distributed among nongovernment standards bodies and using Federal agencies.)

2.3 Order of Precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 Partial-penetration joint design. The term "partial-penetration joint" as used in this standard is defined as a weld joint containing an intentionally unfused area in the central portion of the joint. Examples of typical partial-penetration joint designs are shown in figures 1, 2, and 3.

3.2 Radiation angle. This term refers to the angle from any given plane to the central beam of radiation as shown in figure 4.

3.3 Radiograph. A visible image on an X-ray sensitive recording medium produced by the penetration of radiation through the materials being tested as defined in MIL-STD-453.

3.3.1 Radiographic inspection. The use of X–rays or gamma rays to detect discontinuties in material by presenting their images on a recording medium suitable for interpretation by qualified personnel.

3.3.2 Discontinuity. As defined in ANSI/AWS A3.0, a discontinuity is an interpretation of the typical structure of a weldment, such as a lack of homogeneity in the mechanical, metallurgical or physical characteristics of the material or weldment. A discontinuity is not necessarily a defect.

3.3.2.1 Unfused area. In partial penetration weldments the intentionally unfused area does not constitute a discontinuity, flaw or defect (see 3.1).

3.3.3 Flaw. As defined in ANSI/AWS A3.0, a flaw is a near synonym for discontinuity, but with an undesirable connotation.

3.4 Penetrameter/Image Quality Indicator. A strip of metal the same composition as that of the metal being tested, representing a percentage of object thickness and provided with a combination of steps, holes, and/or slots. Its image on a radiograph is used to determine the radiographic quality level. It is not intended for use in judging the size nor for establishing acceptance limits of discontinuities. Examples of penetrameters are shown in figures 5, 7, 9, 11 and 12.

3.5 Metallographic cross sections. Cross sections through the welds as shown in figures 4 through 15, which are cut perpendicular to the direction of welding, polished and etched as specified in ASTM E340. These samples show internal discontinuity, depth of weld perpetration, weld size, and other characteristics of the weldment.

3.6 Welding terms and definitions. Welding terms and definitions shall be as specified in ANSI/AWS A3.0.

3.6.1 Shielded metal arc welding (SMAW). An arc welding process that produces coalescence by heating with an arc between a covered metal electrode and the workpiece. Shielding is obtained from decomposition of the electrode covering. Pressure is not used, and filler metal is obtained from the electrode.

3.6.2 Gas metal arc welding (GMAW). An arc welding process that produces coalescence by heating with an arc between a continous filler metal electrode and the workplaces. Shielding is obtained entirely from an externally supplied gas.

3.6.3 Gas tungsten arc (GTAW). An arc welding process that produces coalescence with an arc between a tungsten electrode and the workplaces. Shielding is obtained entirely from an externally supplied gas.

3.6.4 Submerged arc welding (SAW). An arc welding process that produces coalescence of metals by heating them with an arc between the bare metal electrode and the workplaces. The arc and molten metal are shielded by a blanket of granular fusible material on the workplaces.

4. GENERAL REQUIREMENTS

4.1 Radiographic location. Weldments shall be radiographically inspected in the location specified on the applicable radiographic position chart drawing, component drawing, specification, or contract requirement. Radiographic inspection shall meet the requirements of MIL-STD-410 and MIL-STD-453.

4.1.1 Radiographic frequency. Establishment of radiographic frequency of spot checking of weldments shall be accomplished in accordance with MTL-STD-1941. A quality assurance plan approved or provided by the procuring activity shall be used.

4.1.2 Radiation angle. Radiographic inspection of partial-penetration welds requires special consideration of joint design when selecting the radiation angle. The angle employed shall insure adequate coverage of the weld with minimum interference from the normally unfused area. Generally this can be achieved by directing the X-ray beam such that any possible incomplete penetration at both roots would be separated on the film by at least 1/8 inch (3.18 millimeter). Figure 4 illustrates the radiographic results of a correct and incorrect radiation angle. If a radiographic position chart is not available the recommended procedures shown on figures 1, 2, and 3 shall be used as a guide.

4.1.3 Penetrameter requirements. Each penetrameter shall be produced with three holes, one of which shall be of a diameter equal to twice the penetrameter thickness (2T). Penetrameters shall conform to the requirements of ASTM E142 and MIL-STD-453.

4.2 Acceptance standards. Designation of acceptance standards for each type of discontinuity illustrated in the reference standards shall be made by the Government procurement or design agency and shall be indicated on the applicable radiographic position chart, drawing, or contract requirement.

4.3 Discontinuity types. With the exception of cracks, the common discontinuities experienced in partial-penetration steel weldments made with the GTAW, SAW, SMAW and GMAW processes are shown in the reference standards forming part of this document. These discontinuities are described below and in figures 5 through 13. All cracks shall be rejected; any deviation from this procedure will require authorization from the Government procuring activity.

a. Scattered porosity (fine and coarse). This flaw consists of scattered voids formed by gases failing to escape during weld metal solidification. On the radiograph these discontinuities are dark round or elongated spots of varying size and density. The average size of fine porosity is 1/32 inch (0.79 millimeter) in diameter and that of coarse porosity is 1/16 inch (1.59 millimeter) in diameter.

b. Clustered porosity. Clustered porosity appears the same as scattered porosity except that the pores are concentrated in one area, generally at the start of a bead or an interrupted arc.

c. Linear porosity. The type most common in partial-penetration welds results from expanding gases generated in the normally unfused area. The cavities are linearly distributed at the root of the weld deposit and generally range from 1/32 inch (0.79 millimeter) in diameter to 1/16 inch (1.59 millimeter) in diameter.

d. Gas cavities. This discontinuity generally results from inadequate shielding gas or severe contamination of the gas. It appears the same as scattered porosity except that the average cavity size is approximately 1/8 inch (3.18 millimeter) in diameter.

e. Incomplete (inadequate) penetration. In partial-penetration welds this discontinuity consists of a linear root void in excess of the unfused area normally present in this type of joint. It appears on the radiograph as a straight dark line at either root or at both roots. When present at both roots the two images should be separated if properly radiographed.

f. Lack of fusion. Lack of fusion is failure of the weld metal to fuse completely with the base metal or with the preceding bead. Lack of fusion resulting from trapped slag appears on the radiograph as a dark elongated line varying in width. Lack of fusion not accompanied by slag generally occurs along the weld interface and produces a hair-line unfused condition. This is difficult to reveal unless the plane of the discontinuity is parallel with the X-ray beam.

4.4 Discontinuity grading. Discontinuity severity grading of the reference standards was selected to extend from standard 1, which represents a high-quality weld, to that of standard 5, which is indicative of poor workmanship and is usually rejected in commercial practice.

5. DETAILED REQUIREMENTS

5.1 Application of reference standards.

5.1.1 Determination of acceptability. Acceptability of production welds shall be determined by directly comparing the production radiograph with the designated reference standard for each type of discontinuity. In general the extent of discontinuity exhibited in the designated standard will be permitted throughout the length of any particular weld joint provided that the discontinuity content in any weld length equal to that of the reference standard does not exceed that shown in the standard. Exceptions to this are required for incomplete penetration and lack of fusion since acceptability of these discontinuities is based on material thickness. The examples shown in figures 14 and 15 are for illustration purposes only; the evaluation is described in 5.1.3.

5.1.2 Quality level of radiographic sensitivity. Figures 5, 7, 9, 11 and 12 illustrate the radiographic image quality level of 2–IT. MIL-STD-453 defines this formula as follows:

Quality level of inspection	1
Penetrameter designation	2 - l T
Maximum penetrameter thickness expressed as a percentage of material thickness, T.	2%
Minimum penetrameter hole diameter expressed as a multiple of thickness of penetrameter	IT
Equivalent penetrameter sensitivity expressed as a percentage of the specimen thickness in which a 2T hole would be clearly visible under the same radiographic conditions	1.4%

5.1.3 Rules 1, 2, and 3. Incomplete penetration and lack of fusion shall be judged by image width and length. Unless otherwise specified by the Government procuring activity the following rules shall apply:

Rule 1. The average image width of any incomplete penetration or lack of fusion shall not exceed 1/16 inch (1.59 millimeter) .

Rule 2. All lines of incomplete penetration having an average image of 1/32 inch (0.79 millimeter) or less shall be acceptable. This amount of incomplete penetration is accepted in steel welds because this amount is not normally compounded with interface lack of fusion as is the case with aluminum welds.

Rule 3. The greatest accumulated length of all incomplete penetration lines in any weld length of 8T, where T equals the average plate thickness, shall not exceed the following:

1T for standard 1
2T for standard 2
4T for standard 3
6T for standard 4
8T for standard 5

5.1.4 Single discontinuity. When the production radiograph shows but one type of discontinuity which is equal to or less severe than the designated standard specified for that type of discontinuity, the weld shall be considered radiographically acceptable. If the radiograph shows a flaw of greater severity than specified, the weld shall be rejected, unless repair is permitted.

5.1.5 Multiple discontinuities.

a. When the production radiograph shows two or more types of discontinuities to be equal to the designated acceptance standard for each type of discontinuity, then the weld shall be rejected, unless repair is permitted.

b. When the production radiograph shows one predominant type of discontinuity to an extent equal to the designated acceptance standard, and all other types to be less severe than the designated standard, then the weld shall be considered radiographically acceptable.

5.1.6 False indications. At times, radiographic films may indicate weld discontinuities when actually the film is defective. If doubt exists as to whether the discontinuity is in the weld or a film imperfection, then the weld shall be radiographed again.

5.2 Inspection records. Radiographic reports and films shall be made available to the procuring activity in accordance with MIL–STD-453.

6. NOTES

6.1 Changes from previous issue. Vertical lines or asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

6.2 Subject term (key word) listing.

Fusion Welding
Inspection
Partial Penetration Welds
Radiation Angles
Radiographic
Steel Welding
Reference Standards

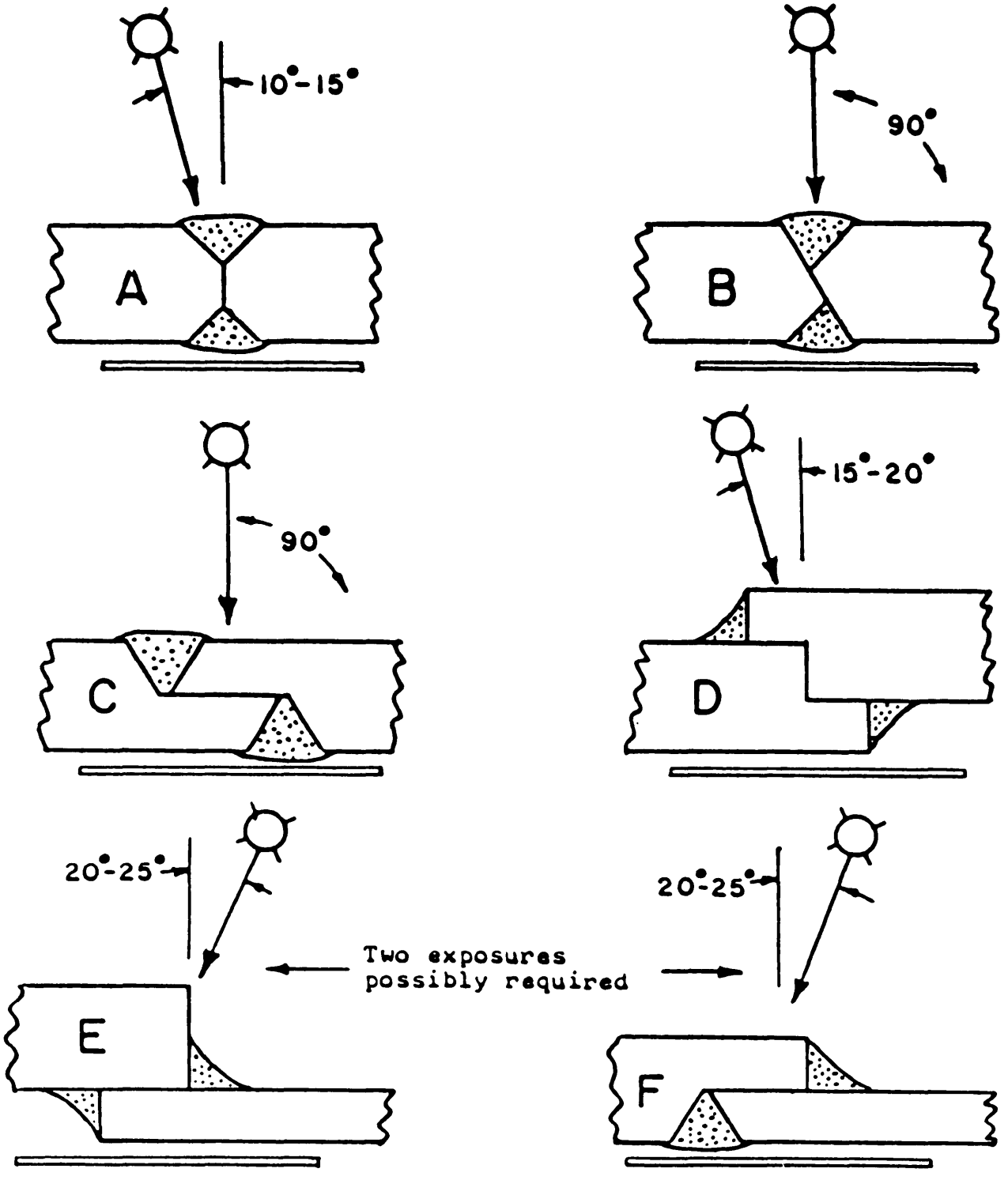


FIGURE 1. Recommended radiation angle and film location for typical partial-penetration joints.

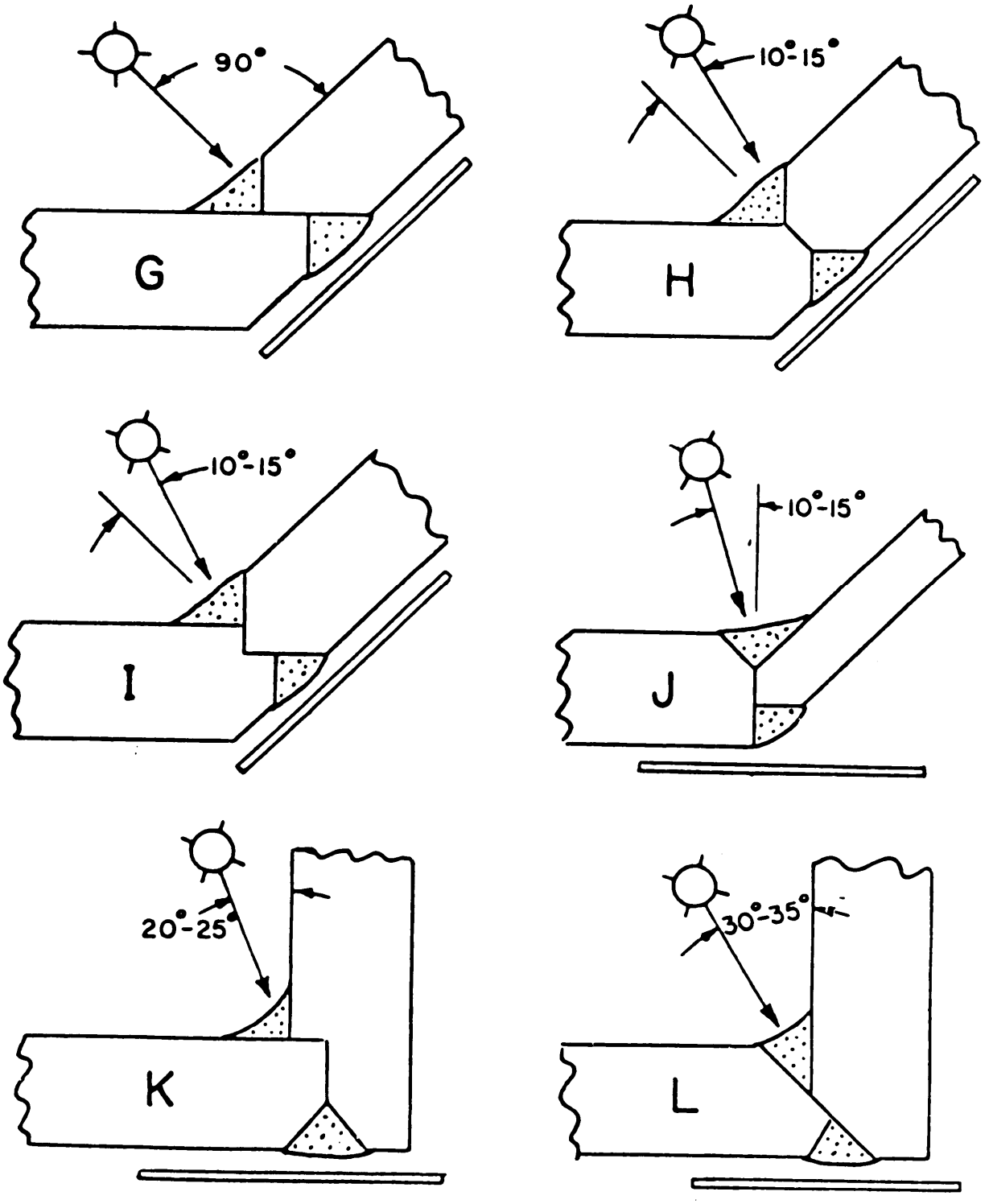


FIGURE 2. Recommended radiation angle and film location for typical partial-penetration joints.

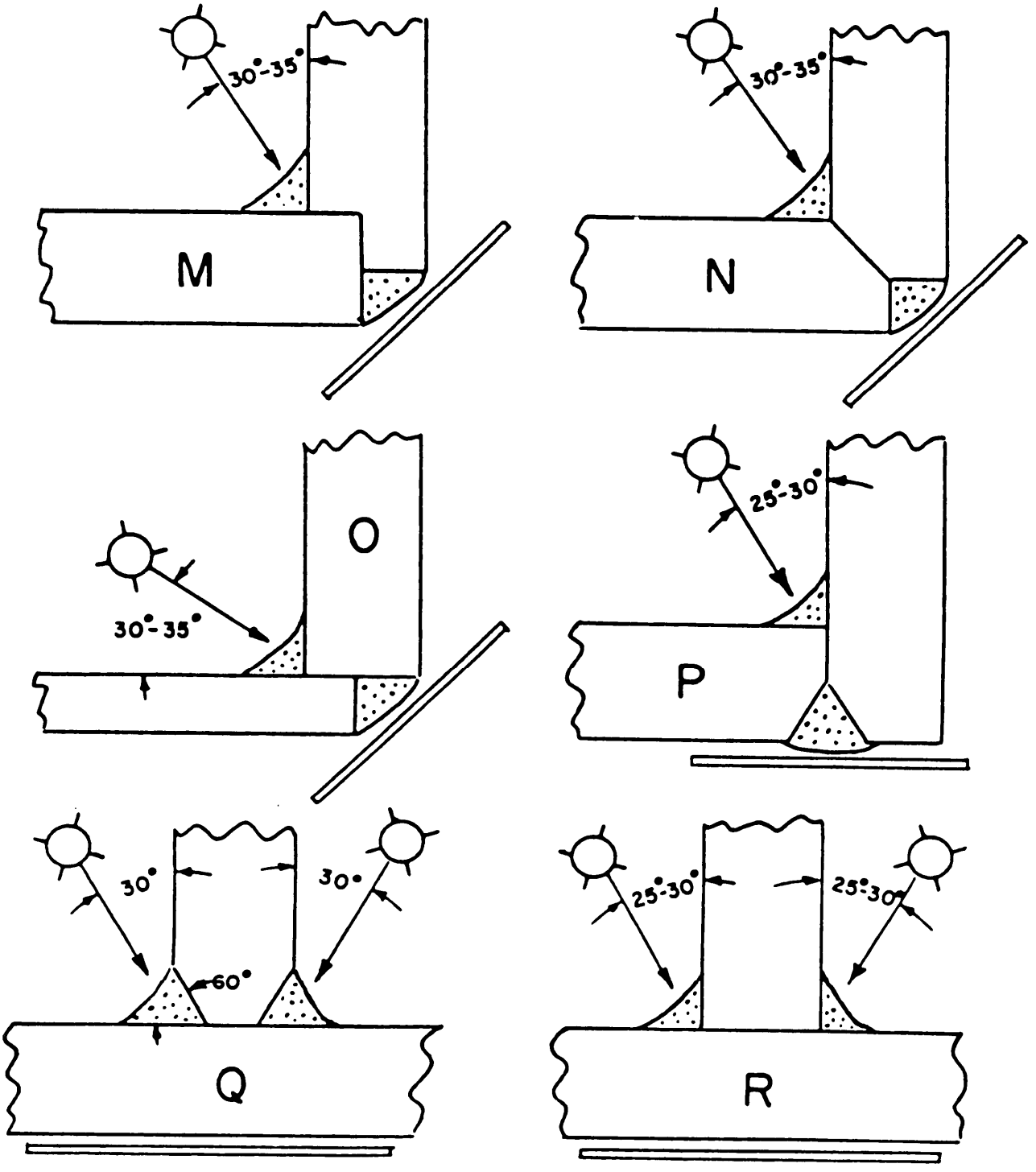
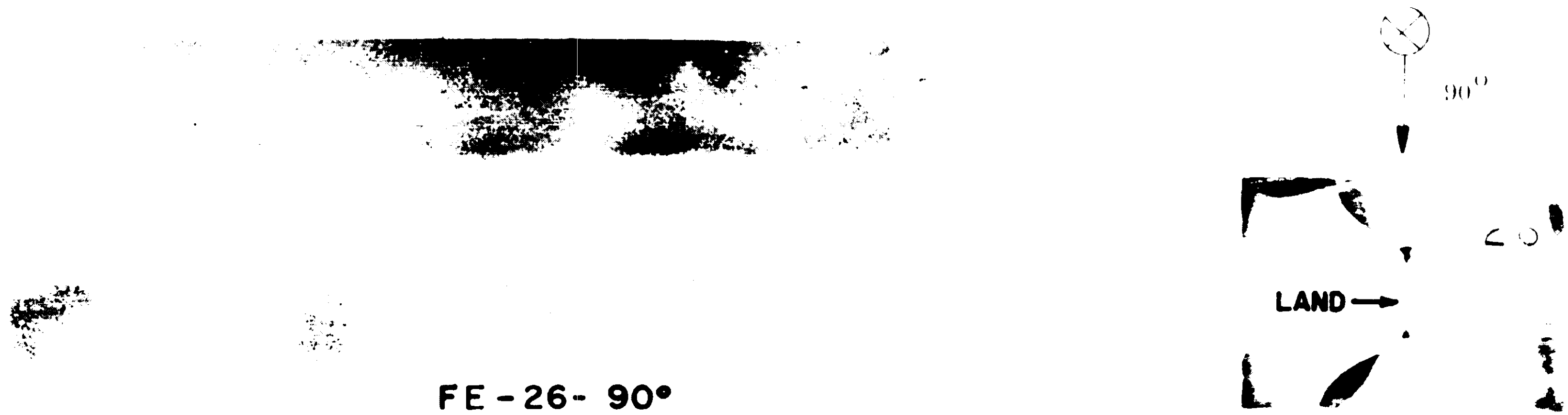


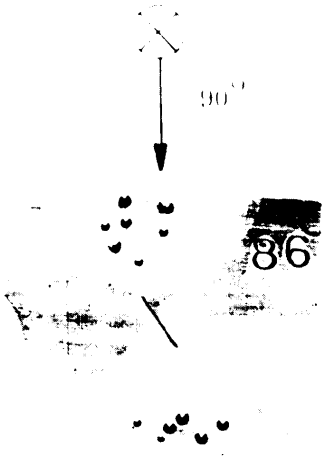
FIGURE 3. Recommended radiation angle and film location for typical partial-penetration joints.

CORRECT PROCEDURE — INCOMPLETE PENETRATION AT BOTH ROOTS IS SEPARATED FROM LAND IMAGE.



INCORRECT PROCEDURE — INCOMPLETE PENTRATION IS IN LINE WITH LAND IMAGE AND CAN NOT BE EVALUATED.

FIGURE 4. Correct and incorrect radiographic procedure for joint design (A).



2-1T RADIOGRAPHIC SENSITIVITY

←CROSS SECTION OF FINE SCATTERED POROSITY. MOST PLATES ARE JOINT B, RADIOGRAPHED AS ILLUSTRATED.

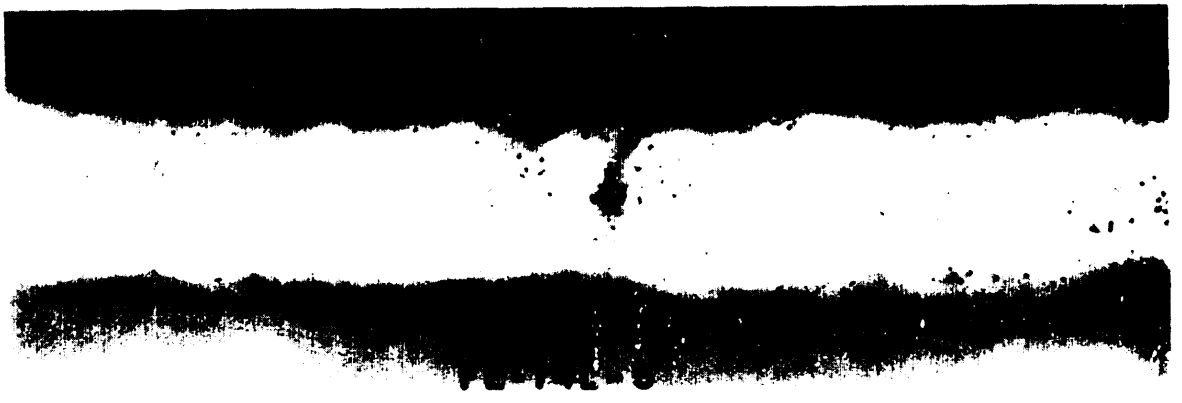
STD. 1 (APPROX. 6 PORES PER SQ. IN.)

STD. 2 (APPROX. 12 PORES PER SQ. IN.)

Figure 5: Reference standards for fine Scattered porosity in steel welds.

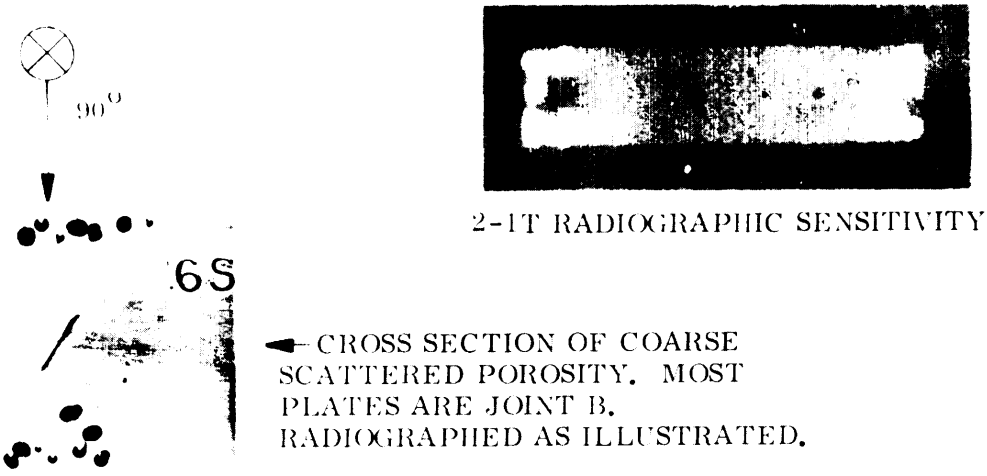
STD. 3 (APPROX. 25 PORES PER SQ. IN.)

STD. 4 (APPROX. 50 PORES PER SQ. IN.)



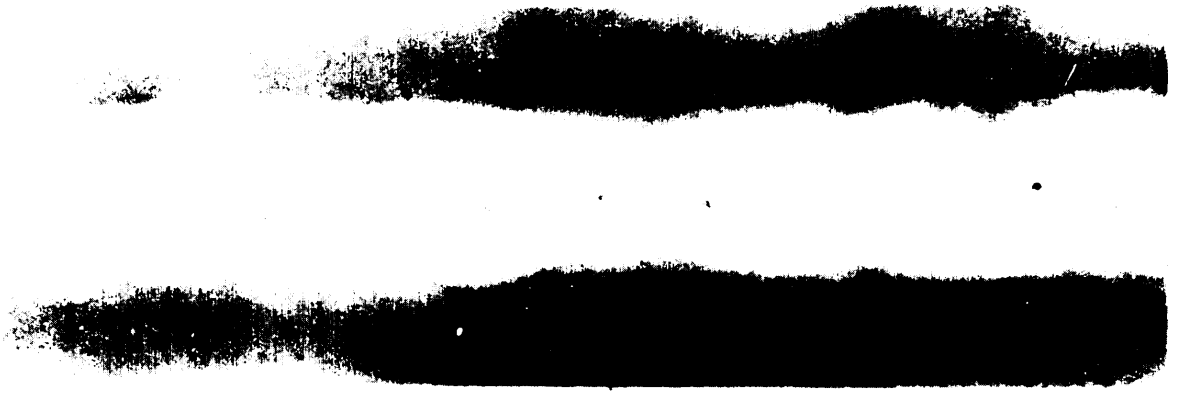
STD. 5 (APPROX. 100 PORES PER SQ. IN.)

Figure 6: Reference standards for line Scattered porosity in steel welds.



2-1T RADIOGRAPHIC SENSITIVITY

← CROSS SECTION OF COARSE SCATTERED POROSITY. MOST PLATES ARE JOINT B. RADIOGRAPHED AS ILLUSTRATED.



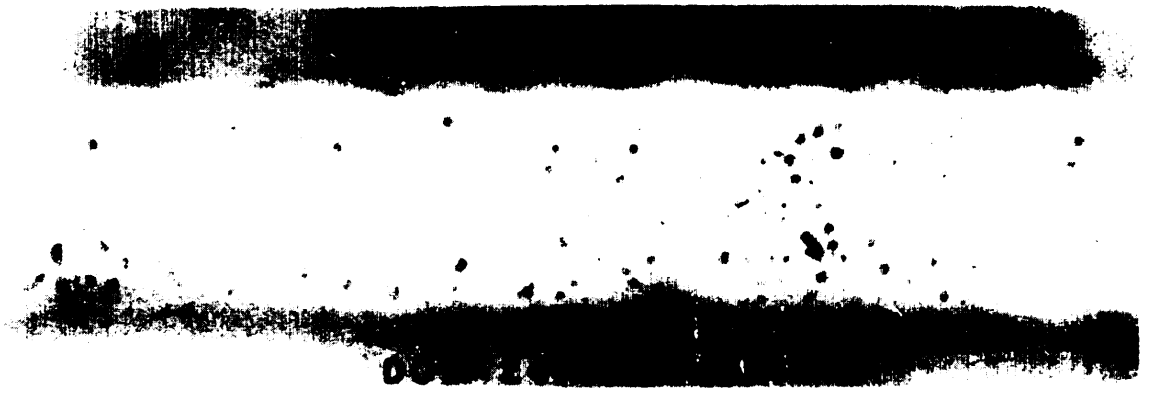
STD. 1 (APPROX. 2 PORES PER SQ. IN.)

STD. 2 (APPROX. 4 PORES PER SQ. IN.)

FIGURE 7: Reference standards for coarse Scattered porosity in steel welds.

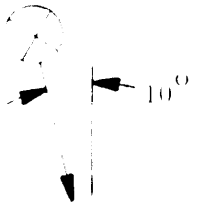
STD. 3 (APPROX. 8 PORES PER SQ. IN.)

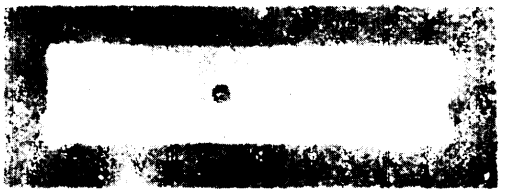
STD. 4 (APPROX. 16 PORES PER SQ. IN.)



STD. 5 (APPROX. 32 PORES PER SQ. IN.)

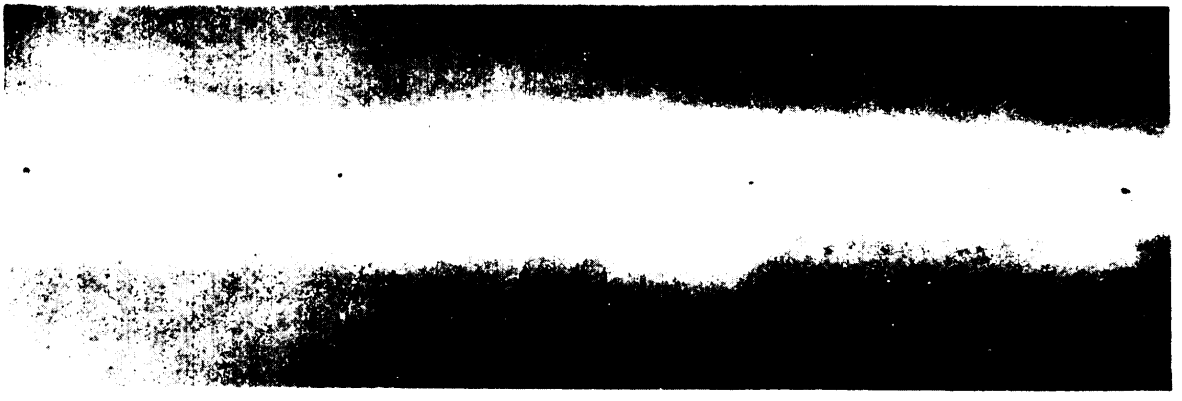
Figure 8: Reference standards for coarse Scattered porosity in steel welds.



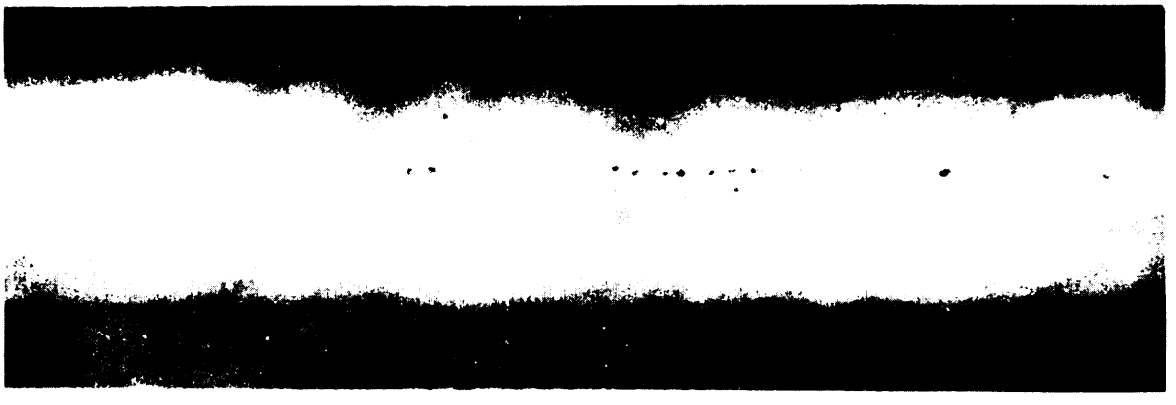


2-1T RADIOGRAPHIC SENSITIVITY

←CROSS SECTION OF LINEAR POROSITY. ALL PLATES ARE JOINT A, RADIOGRAPHED AS ILLUSTRATED.



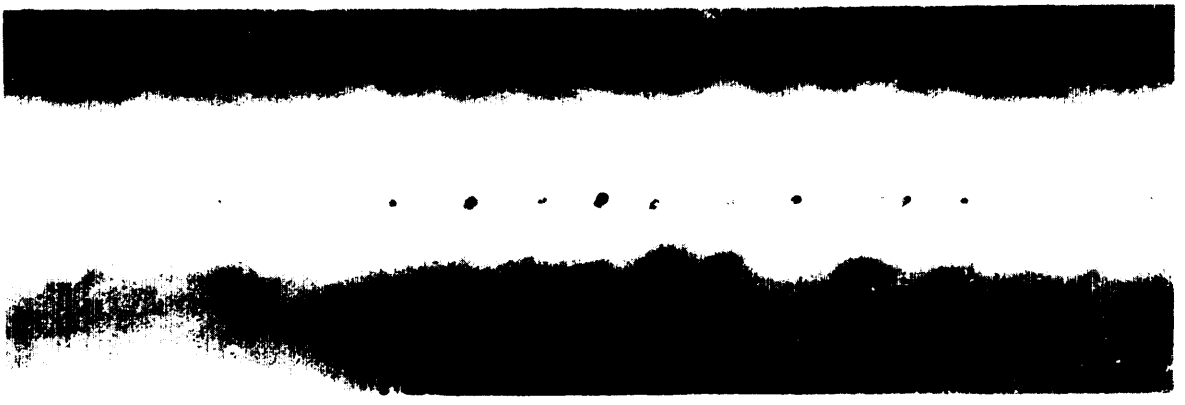
STD. 1



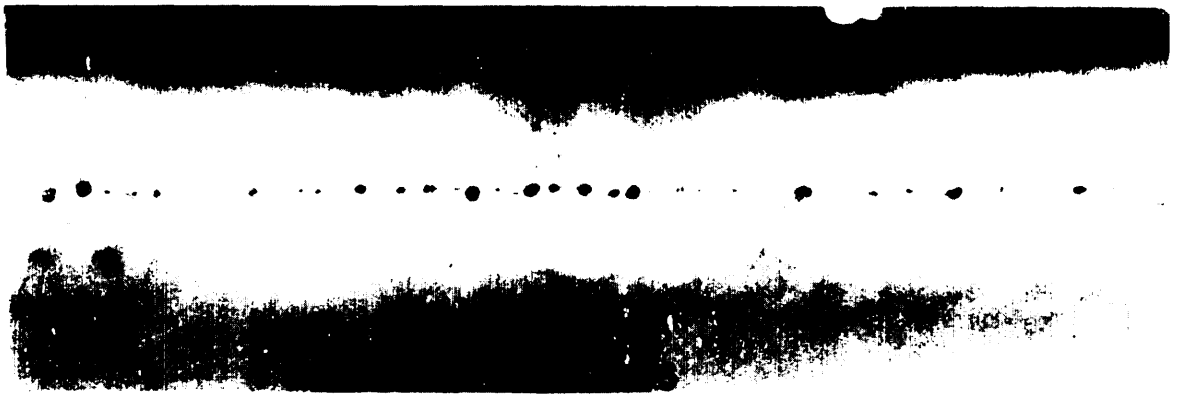
STD. 2

Figure 9: Reference standard for Linear porosity in stee; welds.

STD. 3

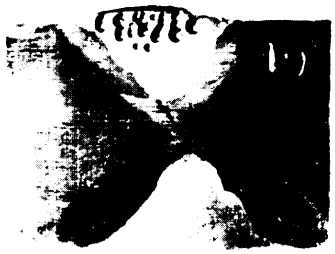


STD. 4

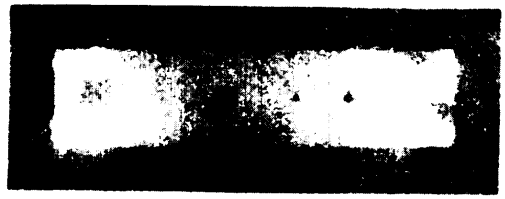


STD. 5

Figure 10: Reference Standards for linear Porosity in steel welds.



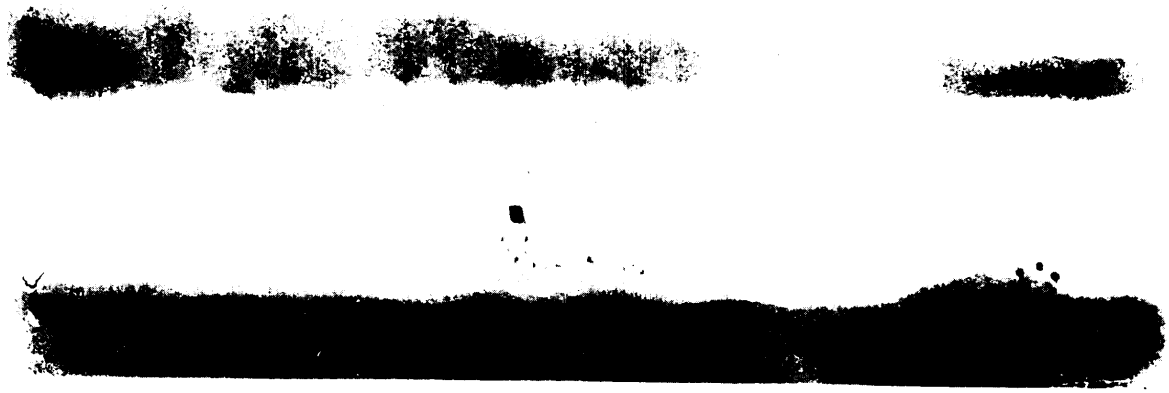
CROSS SECTION VIEW



2-1T RADIOGRAPHY SENSITIVITY

STD. 1

STD. 2



STD. 3

Figure 11: Reference standards for clustered Porosity in steel welds.

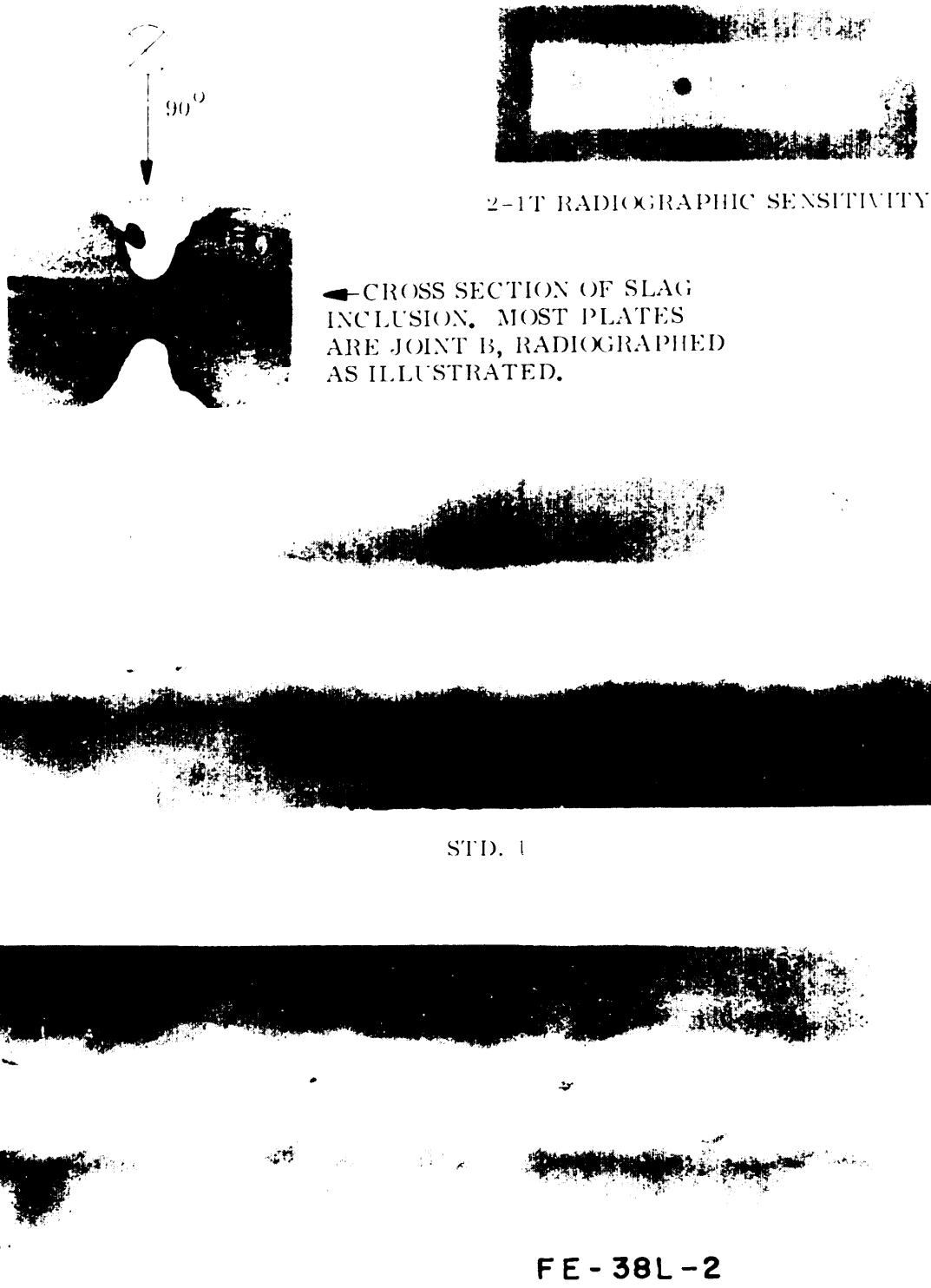


FIGURE 12: Reference standards for scattered Slag inclusions in steel welds.

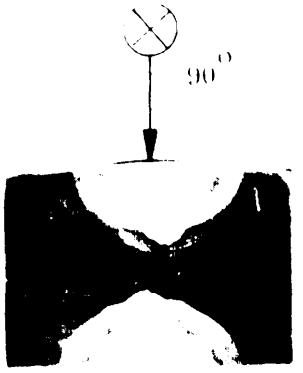
STD. 3

STD. 4

STD. 5

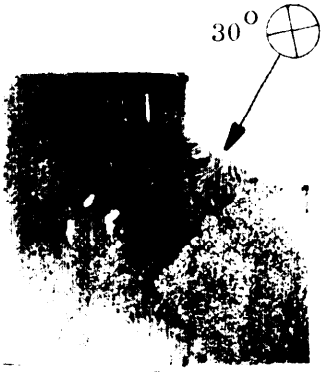
FIGURE 13: Reference standards for scattered slag inclusion in steel welds.

SLIGHT CONDITION — NORMAL FOR THIS JOINT USING STICK ELECTRODE.

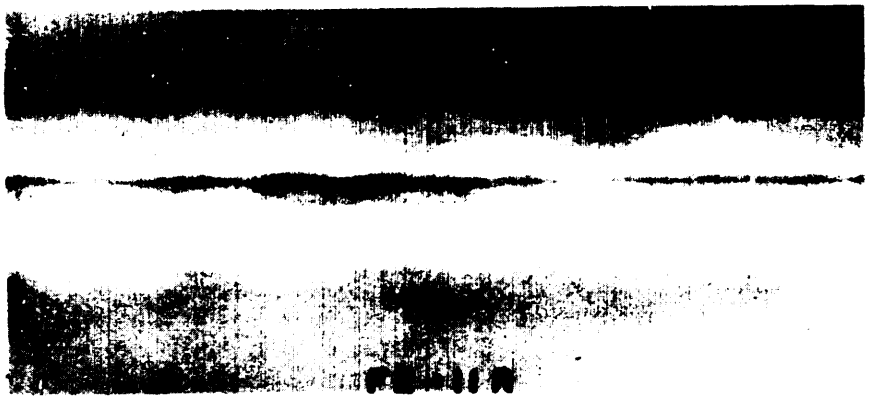


JOINT B

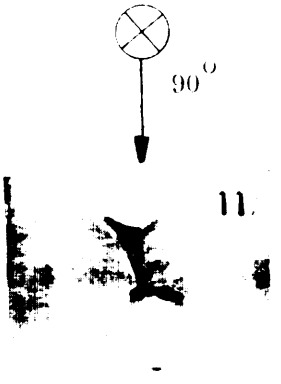
MODERATE CONDITION — RESULTING FROM TOO LARGE AN ELECTRODE ON ROOT PASSES.



JOINT C

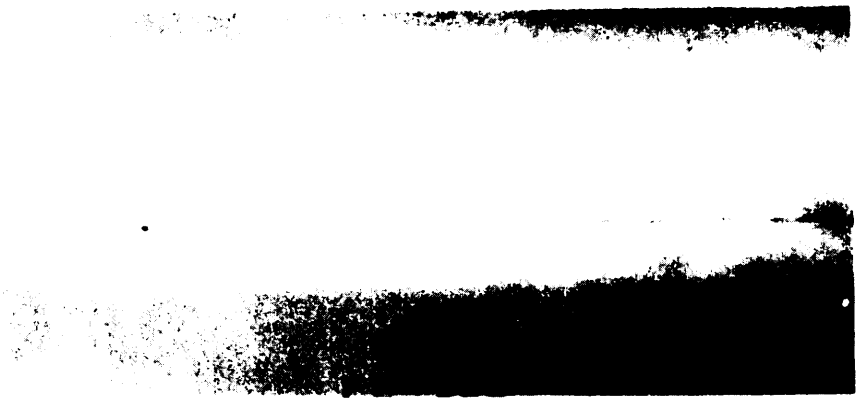


GROSS CONDITION — RESULTING FROM LOW HEAT AND TOO LARGE AN ELECTRODE.

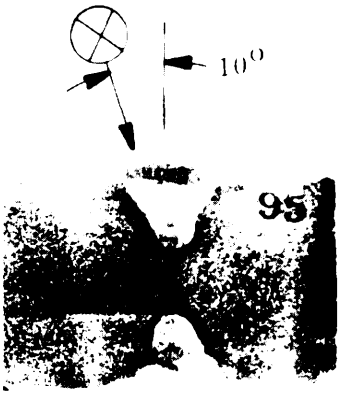


JOINT L

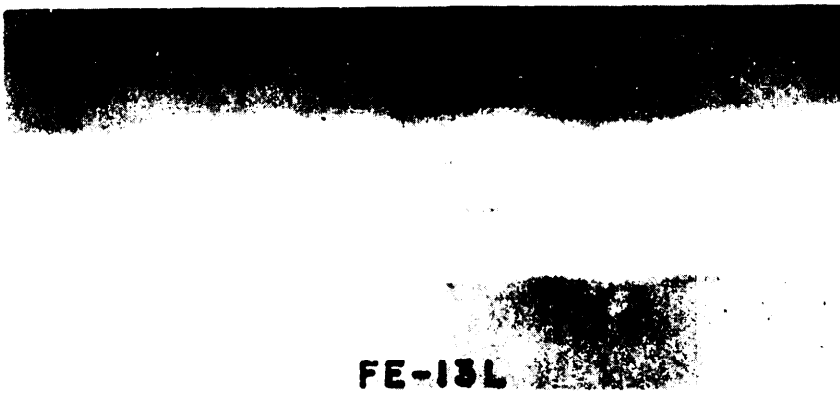
FIGURE 14: Varing degrees of incomplete penetration in steel welds correlated with weld cross sections.



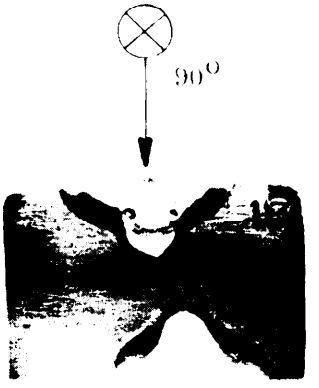
LACK OF FUSION CAUSED BY TRAPPED SLAG BETWEEN WELD BEADS.



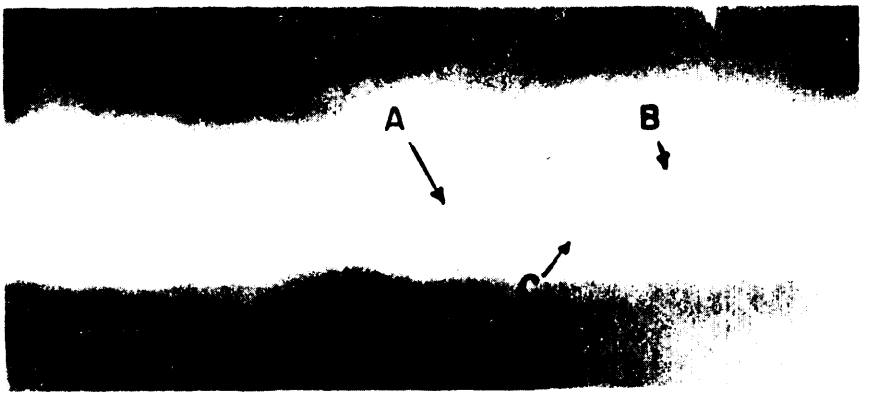
JOINT A



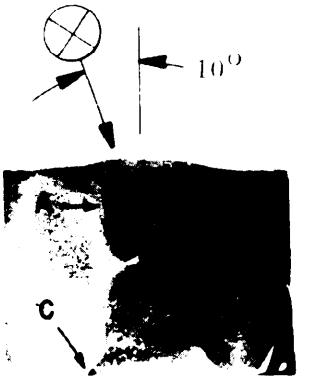
SLAG TRAPPED IN SHARP NOTCHES PRODUCED BY A HIGH CROWN BEAD.



JOINT B



SEVERE CONDITION DUE TO POOR GUN ANGLE, ALSO SHARP NOTCH EFFECT AT C.



JOINT A

FIGURE 15: Lack of fusion in steel welds correlated with weld cross sections.

Custodians:
Army - AT
Air Force - 20

Review Activities:
Army - AR, AV

Preparing activity:
Army - AT

(Project NDTI-0122)

 U.S. GOVERNMENT PRINTING OFFICE: 1986 - 704-036/45871

considered.

NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document*(s)* or to amend contractual requirements.

(Fold along this line)

(Fold along this line)

DEPARTMENT OF THE ARMY

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 12062 WASHINGTON D. C.
POSTAGE WILL BE PAID BY THE DEPARTMENT OF THE ARMY

[redacted]

US Army Tank-Automotive Command
ATTN: AMSTA-GDS
Warren, MI 48397-5000

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER *(Specify)*: _____

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 82 MAR 1426 PREVIOUS EDITION IS OBSOLETE.

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)