INCH-POUND
MIL-STD-1895B(AT)
26 June 1998
SUPERSEDING
MIL-STD-1895A
20 October 1986

DEPARTMENT OF DEFENSE STANDARD PRACTICE

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

AMSC N/A AREA NDTI

FOREWORD

1. This standard is approved for use by the U.S. Army Tank-automotive and Armaments Command, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

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

3. 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.

4. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: U.S. Army Tank-automotive and Armaments Command, ATTN: AMSTA-TR-E/BLUE, Warren, MI 48397-5000, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

CONTENTS

FIGURES

1. SCOPE

1.1 Scope. This standard provides standard reference radiographs and recommended radiographic inspection procedures for partial-penetration weldments in aluminum plate, casting, or forging, 0.5 to 2 inches (in.) (12.70 to 50.80 millimeters (mm)) thick.

1.2 Use of radiographs. The reference radiographs comprised in this standard are intended primarily for use on welds made with the gas metal arc welding and gas tungsten processes and may be manual or machine welded.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this standard.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplements thereto.

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-410 - Nondestructive Testing Personnel Qualification and Certification.

(Note: Negatives of radiographs illustrated in this standard can be purchased through AMSTA-TR-E/BLUE. Requests should be addressed to U.S. Army Tank-automotive and Armaments Command, Attn: AMSTA-TR-/BLUE, Warren, MI 48397-5000.)

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplements thereto.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E142 - Controlling Quality of Radiographic Testing, Method for (DoD Adopted).

ASTM E340 - Standard Method for Macroetching Metals and Alloys (DoD Adopted).

ASTM E1316	- Standard Terminology for Nondestructive Examinations.
ASTM E1742	- Radiographic Examination, Standard Practice for (DoD Adopted).

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Metallographic cross sections. Cross sections through the welds as shown in figures 1 through 8, 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 penetration, weld size, and other characteristics of the weldment.

3.2 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. Examples of typical partial-penetration joint designs are shown in figure 9.

3.3 Penetrameter/Image Quality Indicator (IQI). 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/IQIs are shown in figures 2, 3, 4, 5 and 6.

3.4 Nondestructive testing terms and definitions. Nondestructive testing terms and definitions are as specified in ASTM E1316.

4. GENERAL REQUIREMENTS

4.1 Radiographic location. Weldments are 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 ASTM E1742.

4.1.1 Radiographic frequency. Establishing radiographic frequency of spot checking of weldments shall be accomplished in accordance with a Government approved quality assurance plan. The frequency of spot-checking and selection of the applicable standard has historically been based on the importance of the particular joint.

4.1.2 Angle beam. 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 minimal 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 0.125 in. (3.18 mm). Figure 1 illustrates the radiographic results of a correct and incorrect radiation angle. If a radiographic position chart is not available, the recommended procedures shown on figure 9 shall be used as a guide.

4.1.3 Penetrameter/IQI requirements. Each penetrameter/IQI shall be produced with three holes, one of which shall be a diameter equal to twice the penetrameter/IQI thickness (2T). Penetrameter/IQI requirements are given in ASTM E142 and ASTM E1742.

4.2 Acceptance standards. Designation of acceptance standards for each type of discontinuity illustrated in the reference standards shall be made by the design activity and approved by the Government procurement agency. The specific level of acceptance shall be designated by the “Standard Level” which is the minimum acceptance level for that discontinuity. The standard level shall be documented 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 aluminum weldments made are shown in the reference standards forming part of this document. These discontinuities are described below and in figures 2 through 6. All cracks have historically been rejected and 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 gasses 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 0.031 in. (0.79 mm) in diameter and that of coarse porosity is 0.063 in. (1.59 mm) 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 gasses generated in the normally unfused area. The cavities are linearly distributed at the root of the weld deposit and generally range from 0.031 in. (0.79 mm) in diameter to 0.063 in. (1.59 mm) 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 0.125 in. (3.18 mm) 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 between the weld metal and base metal is most common in aluminum welds and is generally associated with incomplete penetration near the root of the weld. Examples of this are illustrated in figures 7 and 8. This discontinuity is very difficult to detect radiographically due to its hair-line condition and interference from the incomplete penetration void.

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 those discontinuities is based on material thickness. The examples shown in figures 7 and 8 are for illustration purposes only; the evaluation is described in 5.1.3.

5.1.2 Quality level of radiographic sensitivity. Figures 2, 3, 4, 5 and 6 illustrate the radiographic image quality level of 2-1T. ASTM E1742 defines this formula as follows:

Radiographic quality level	2-1T
Penetrameter/IQI designation	1
Maximum penetrameter/IQI thickness expressed as a percentage of material thickness, T.	2%
Minimum penetrameter/IQI hole diameter expressed as a multiple of thickness of penetrameter/IQI	1T
Equivalent penetrameter/IQI 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 and 2. 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 should not exceed 0.063 in. (1.59 mm).

Rule 2. The greatest accumulated length of all incomplete penetration lines in any weld length of 8T, where T equals the average plate thickness, should 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 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 ASTM E1742.

6. NOTES

(This section contains information of a general or explanatory nature which may be helpful, but is not mandatory.)

6.1 Intended use. This standard is intended to demonstrate various types and degrees of discontinuities occurring in partial-penetration aluminum welds and to give instructions concerning radiographic inspection of these types of weldments.

6.2 Subject term (key word) listing.

Arc welding
Discontinuity
Fusion Welding
Gas cavities
Inspection
Porosity
Angle Beams
Unfused Area
Weldments

6.3 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

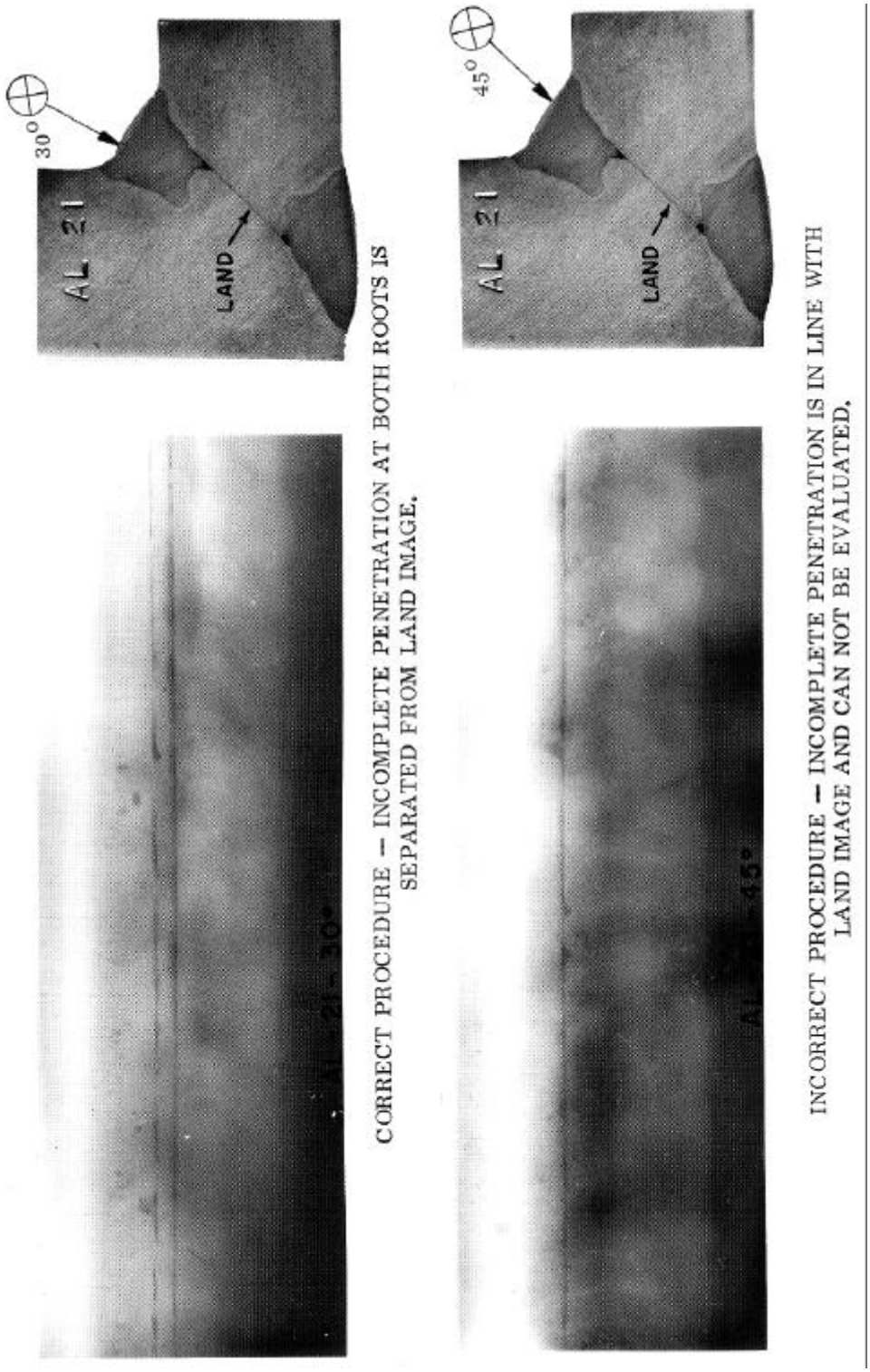
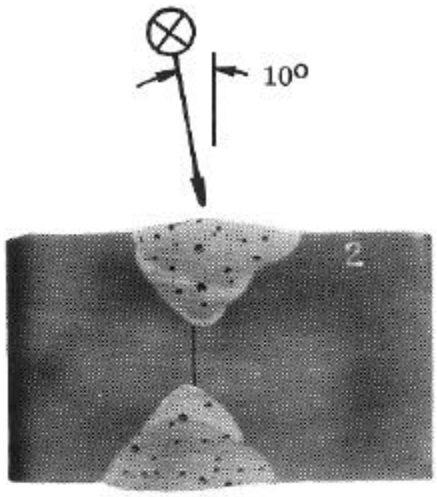
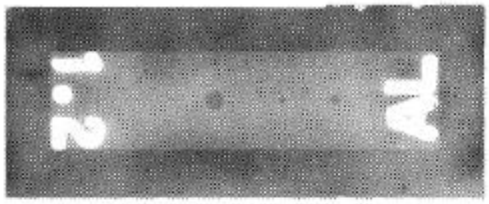


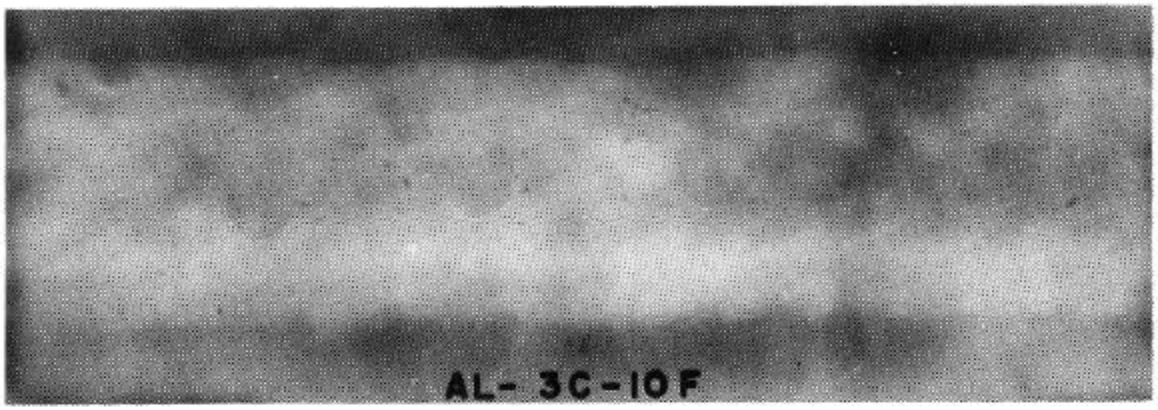
FIGURE 1. Correct and incorrect radiographic procedure for joint design (L).



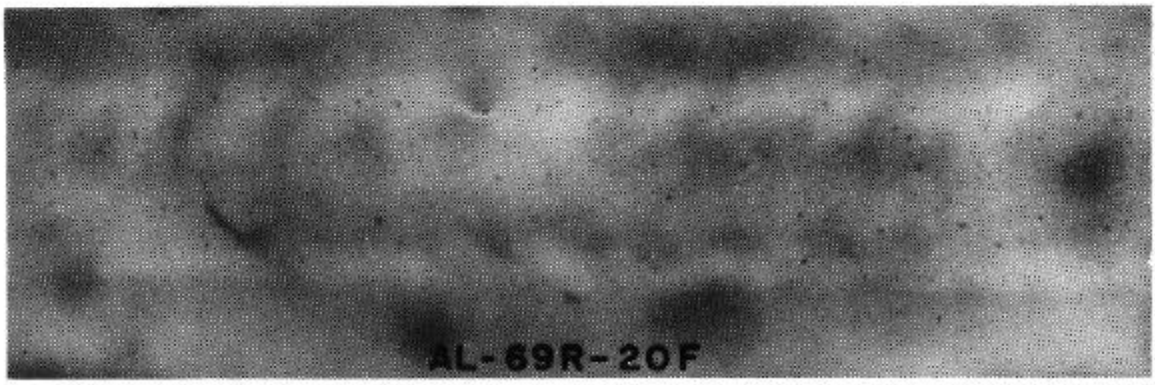


2-1T RADIOGRAPHIC SENSITIVITY

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

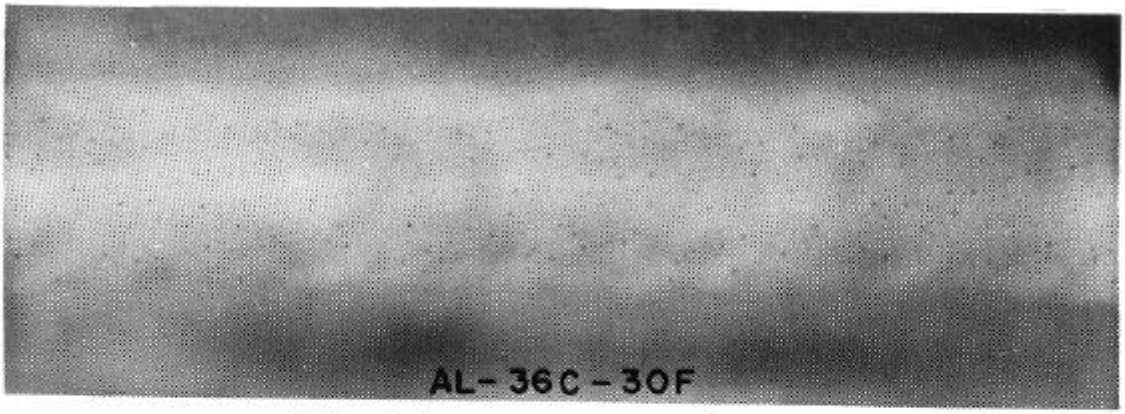


STD. 1 (APPROX. 6 PORES PER. SQ. IN.)

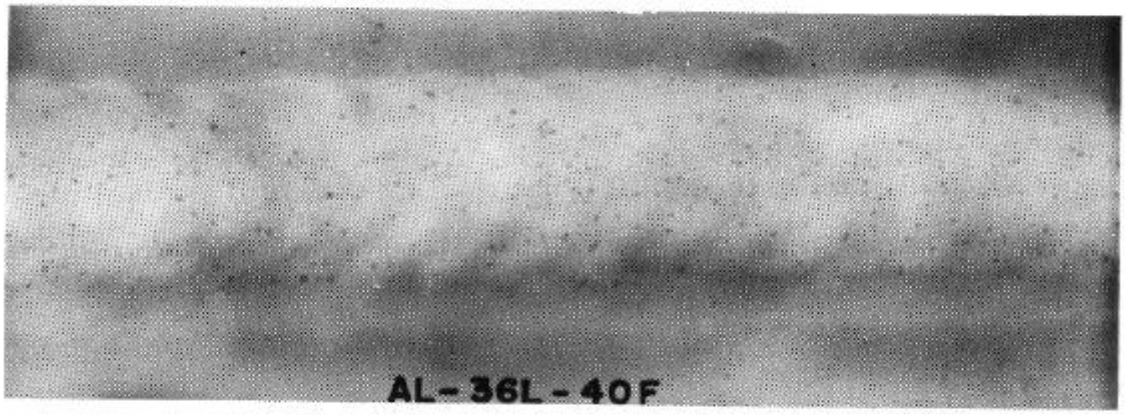


STD. 2 (APPROX. 12 PORES PER. SQ. IN.)

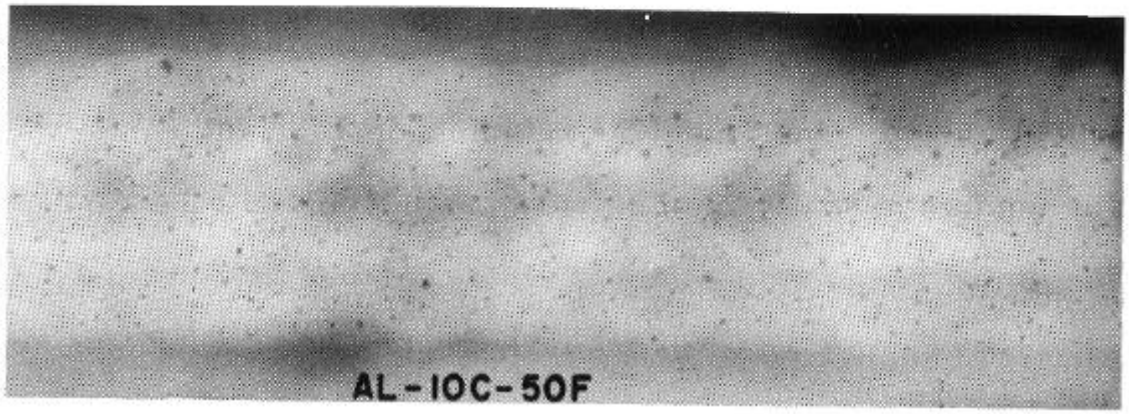
FIGURE 2. Reference standards for fine scattered porosity in aluminum welds.



STD. 3 APPROX. 25 PORES/SQ. IN.

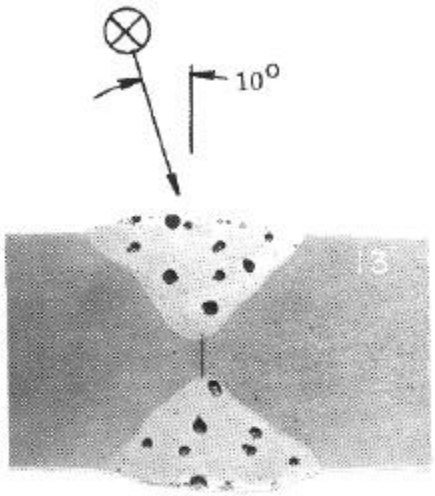


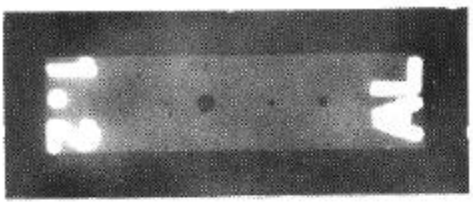
STD. 4 APPROX. 50 PORES/SQ. IN.



STD. 5 APPROX. 100 PORES/SQ. IN.

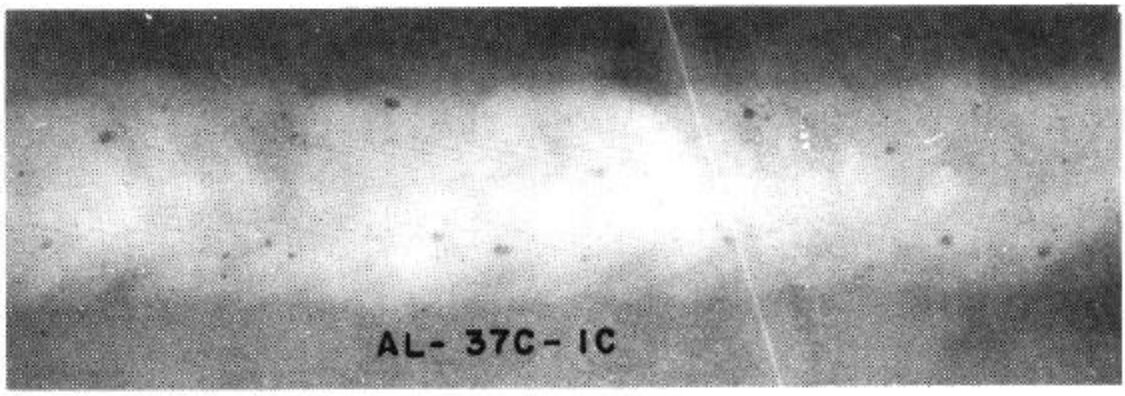
FIGURE 2. Reference standards for fine scattered porosity in aluminum welds - Continued.



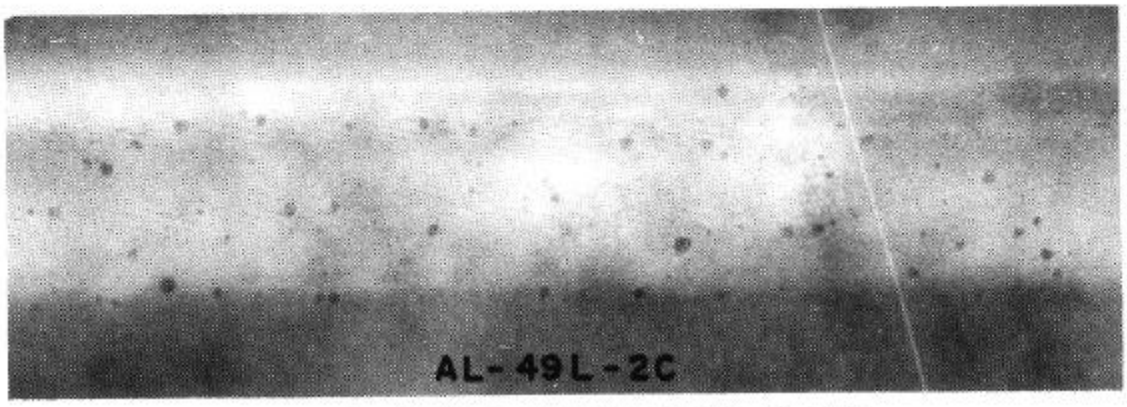


2-1T RADIOGRAPHIC SENSITIVITY

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

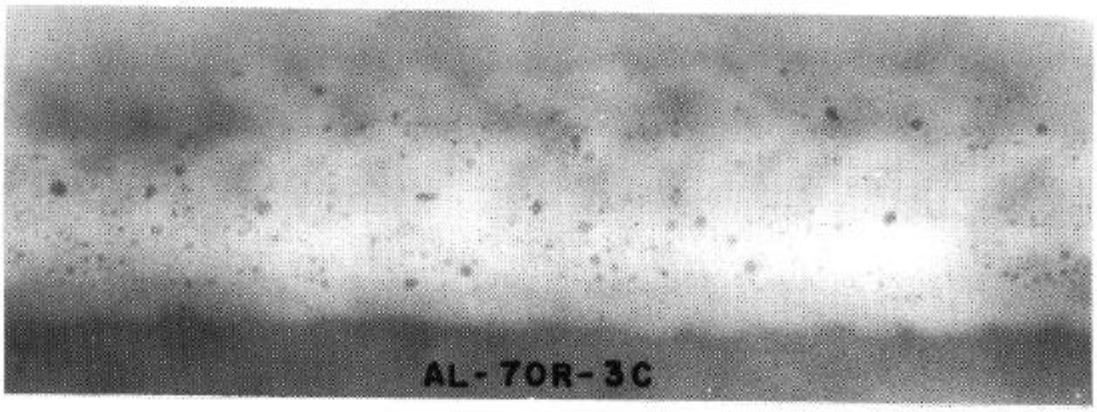


STD. 1 (APPROX. 2 PORES PER. SQ. IN.)

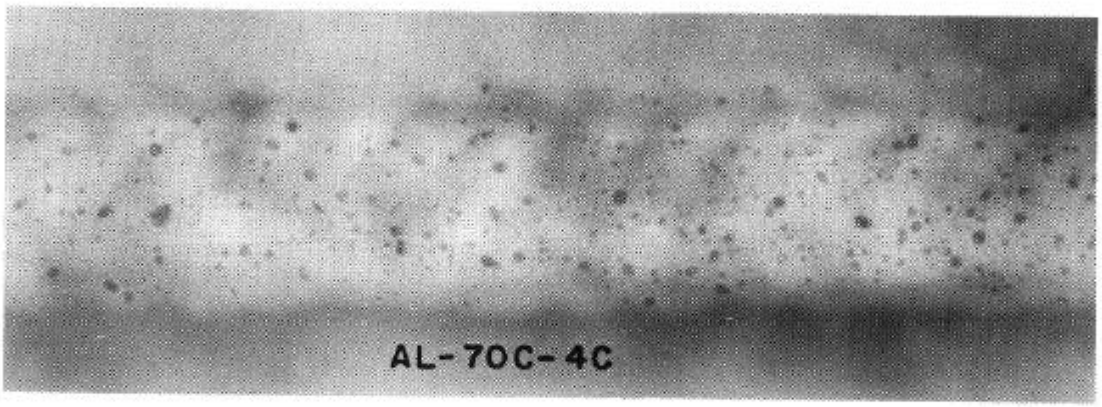


STD. 2 (APPROX. 4 PORES PER. SQ. IN.)

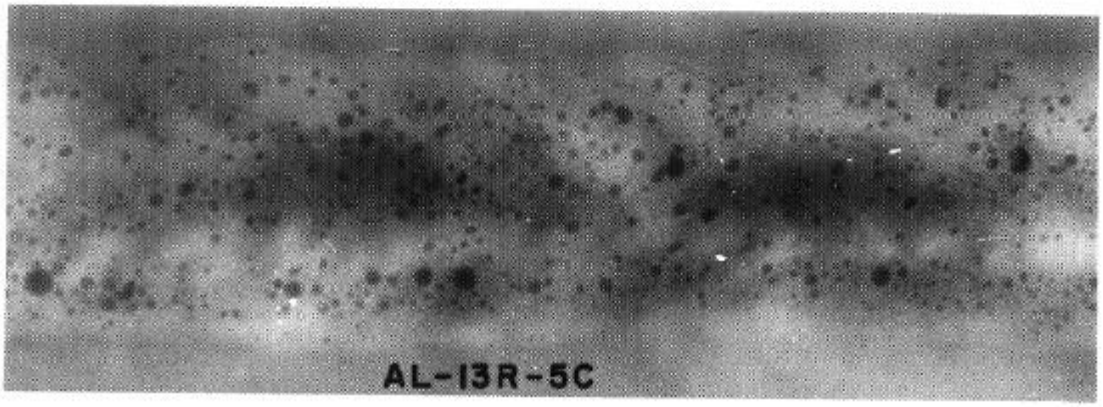
FIGURE 3. Reference standards for coarse scattered porosity in aluminum welds.



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

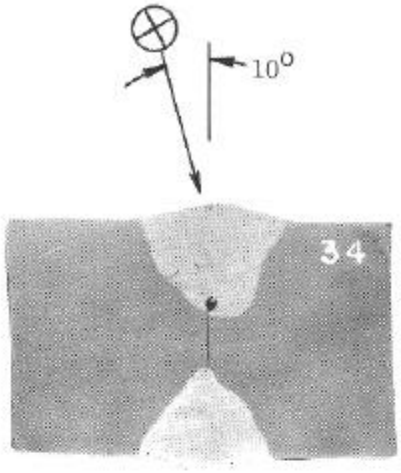


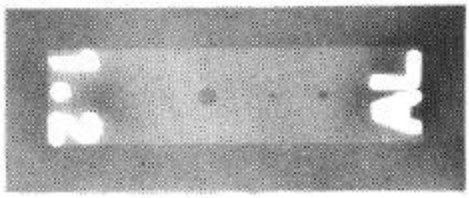
STD. 4 (APPROX. 16 PORES PER. SQ. IN.)



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

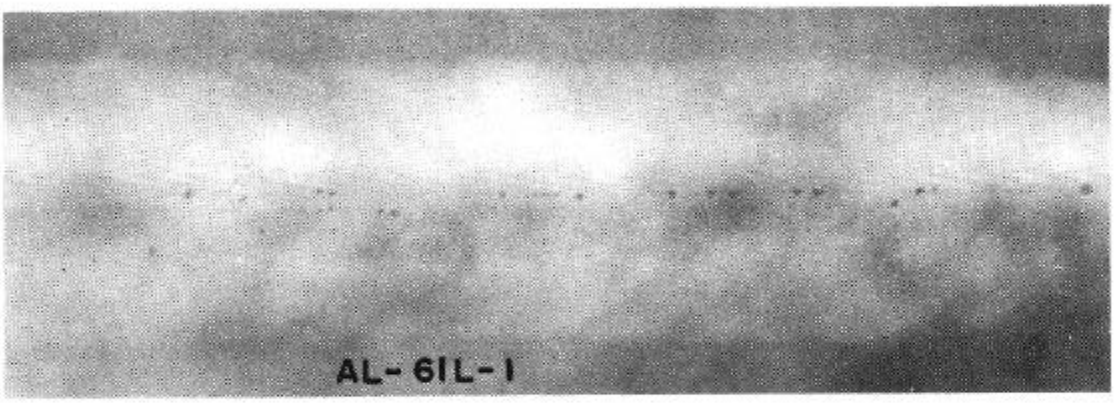
FIGURE 3. Reference standards for coarse scattered porosity in aluminum welds - Continued.



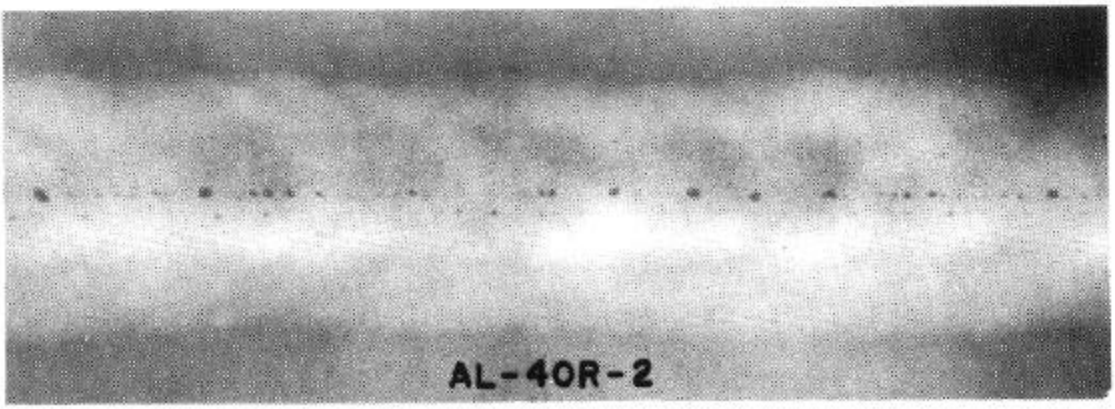


2-1T RADIOGRAPHIC SENSITIVITY

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

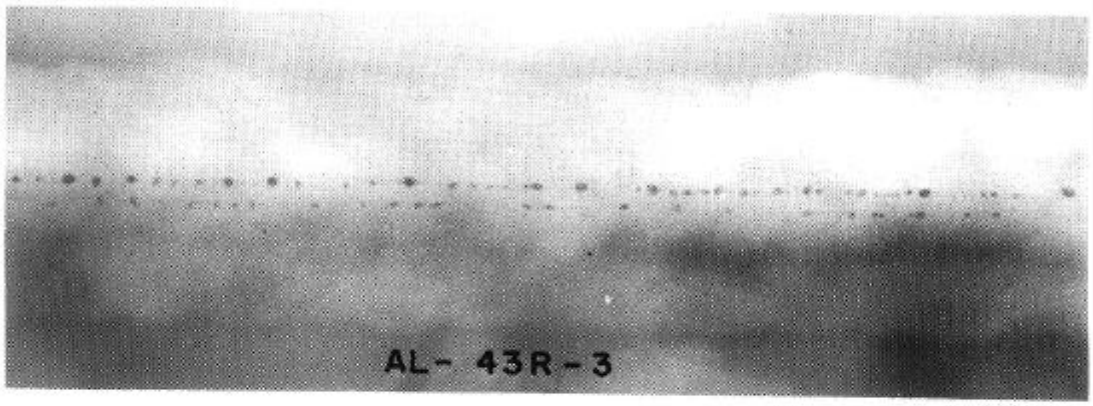


STD. 1

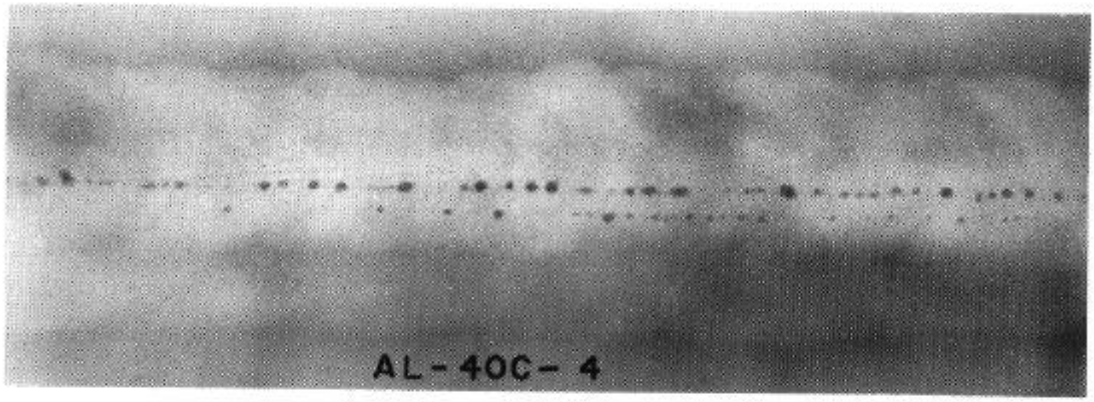


STD. 2

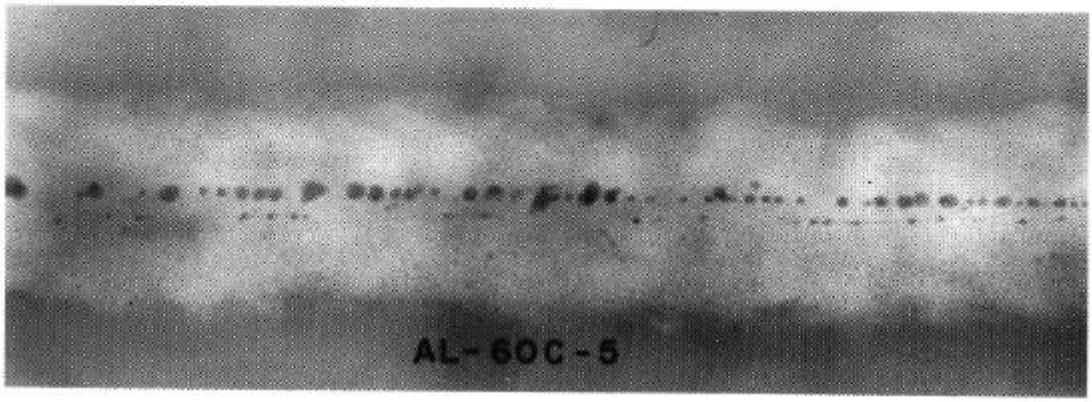
FIGURE 4. Reference standards for linear porosity in aluminum welds.



STD. 3

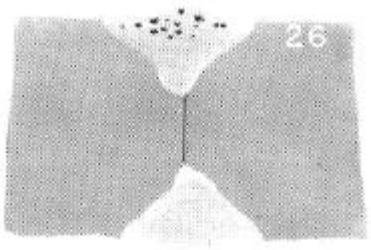


STD. 4

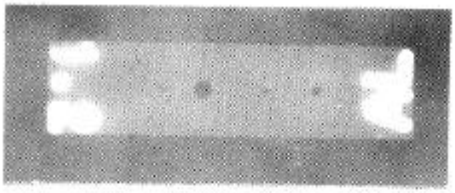


STD. 5

FIGURE 4. Reference standards for linear porosity in aluminum welds - Continued.



CROSS SECTION VIEW

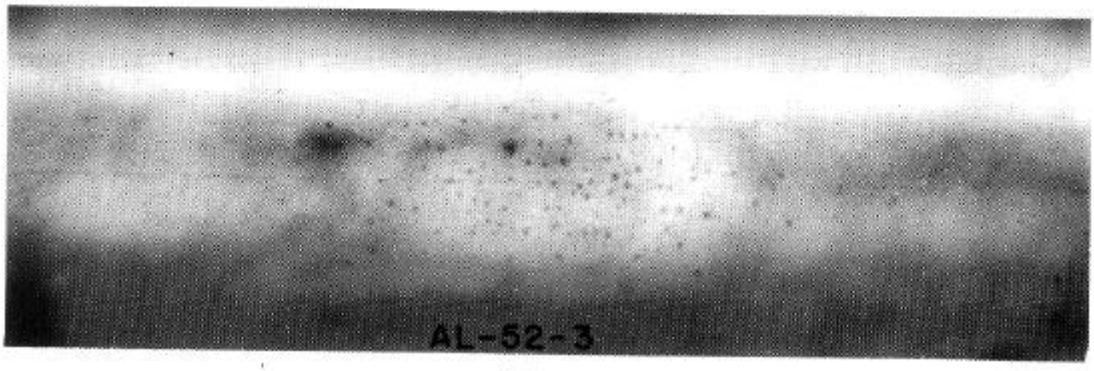


2-1T RADIOGRAPHIC SENSITIVITY

NOTE: Any condition more severe than STD. 3 should be judged as scattered porosity.

STD. 1

STD. 2



STD. 3

FIGURE 5. Reference standards for clustered porosity in aluminum welds.

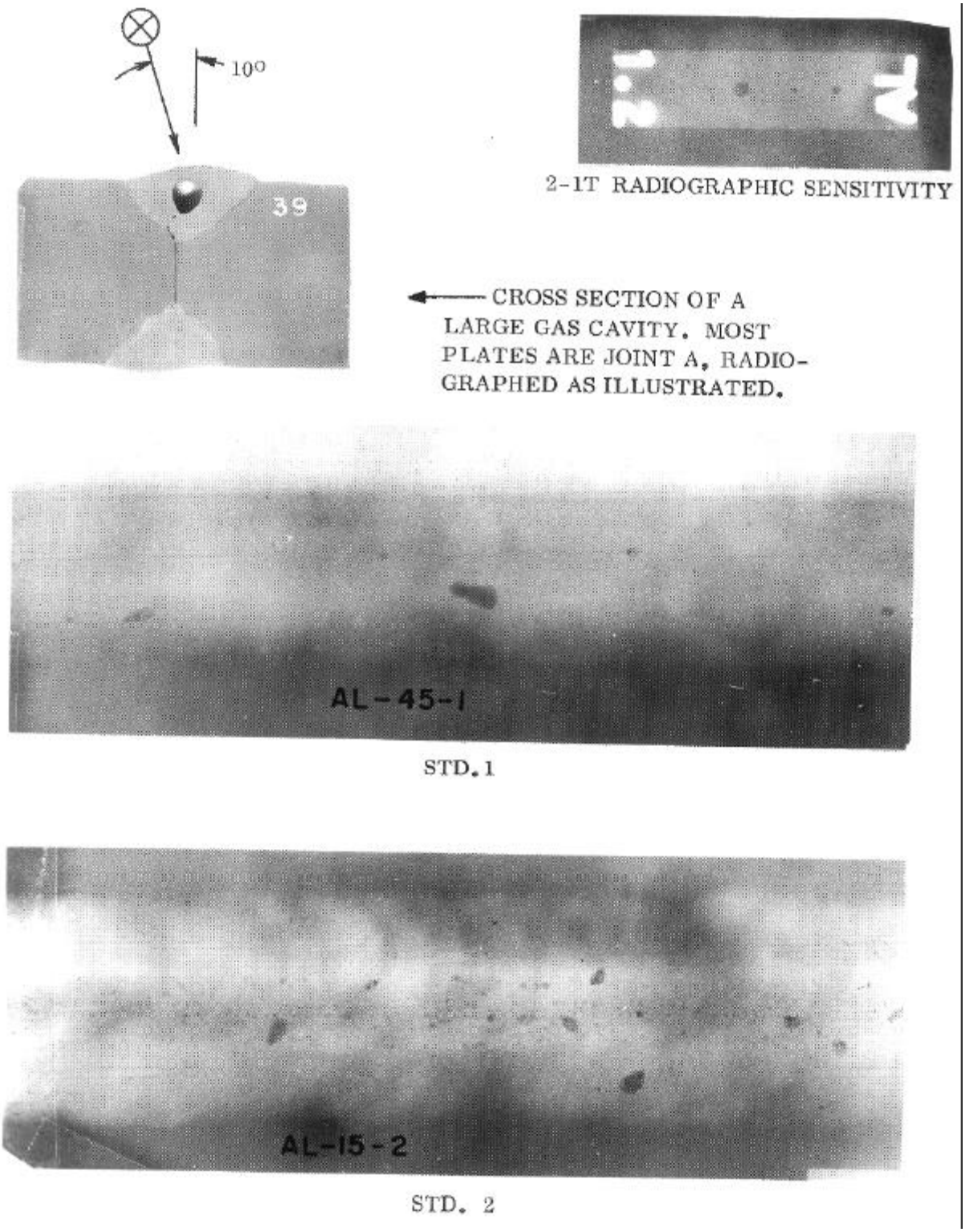
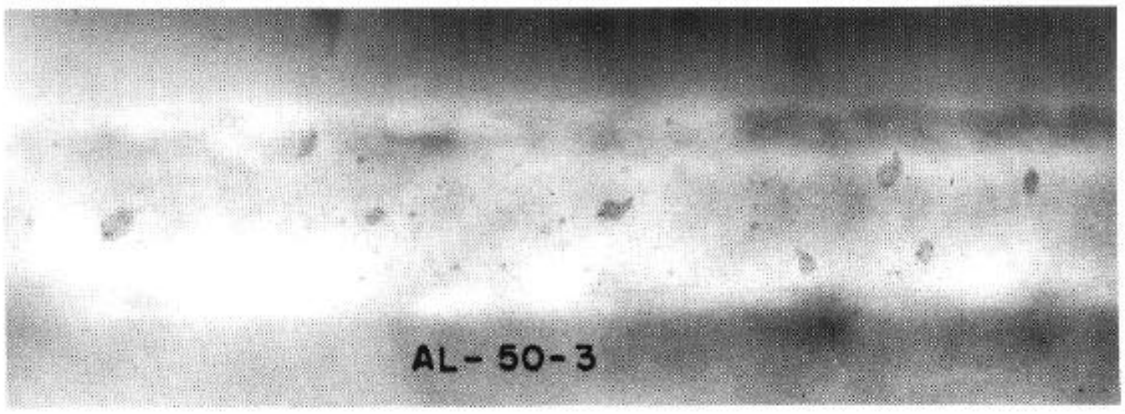
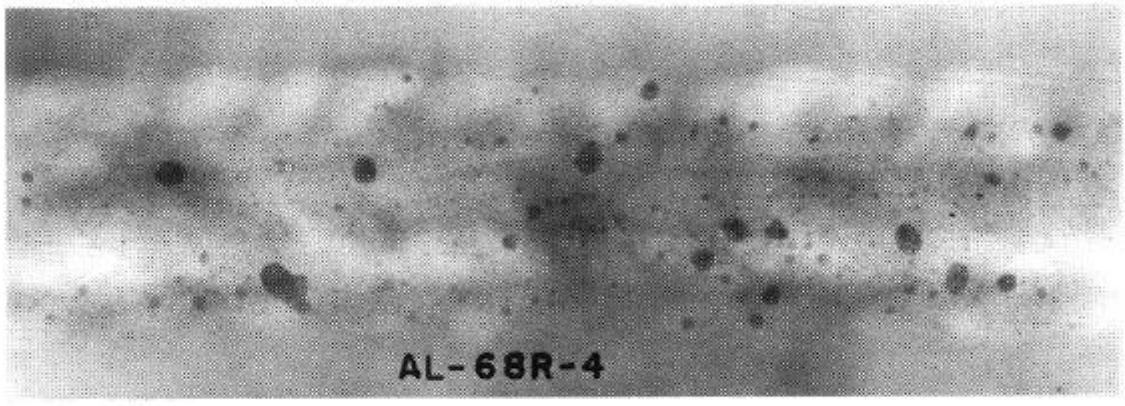


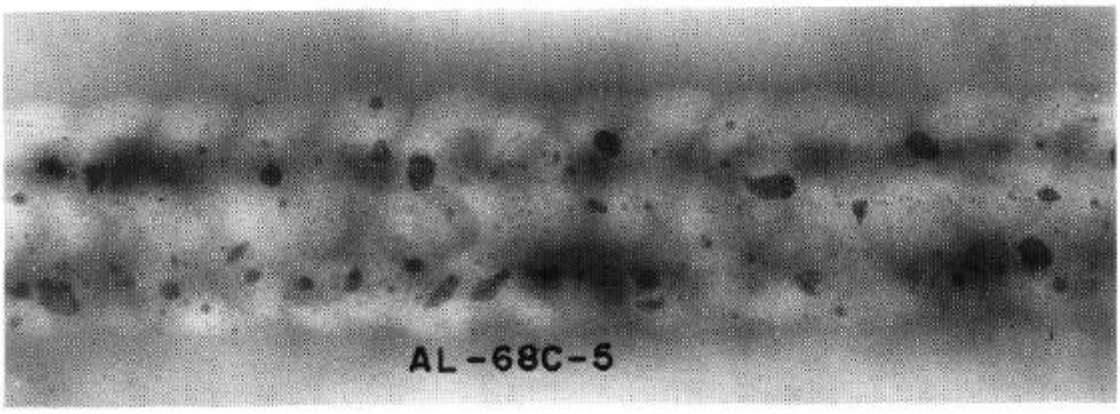
FIGURE 6. Reference standards for gas cavities in aluminum welds.



STD. 3



STD. 4



STD. 5

FIGURE 6. Reference standards for gas cavities in aluminum welds - Continued.

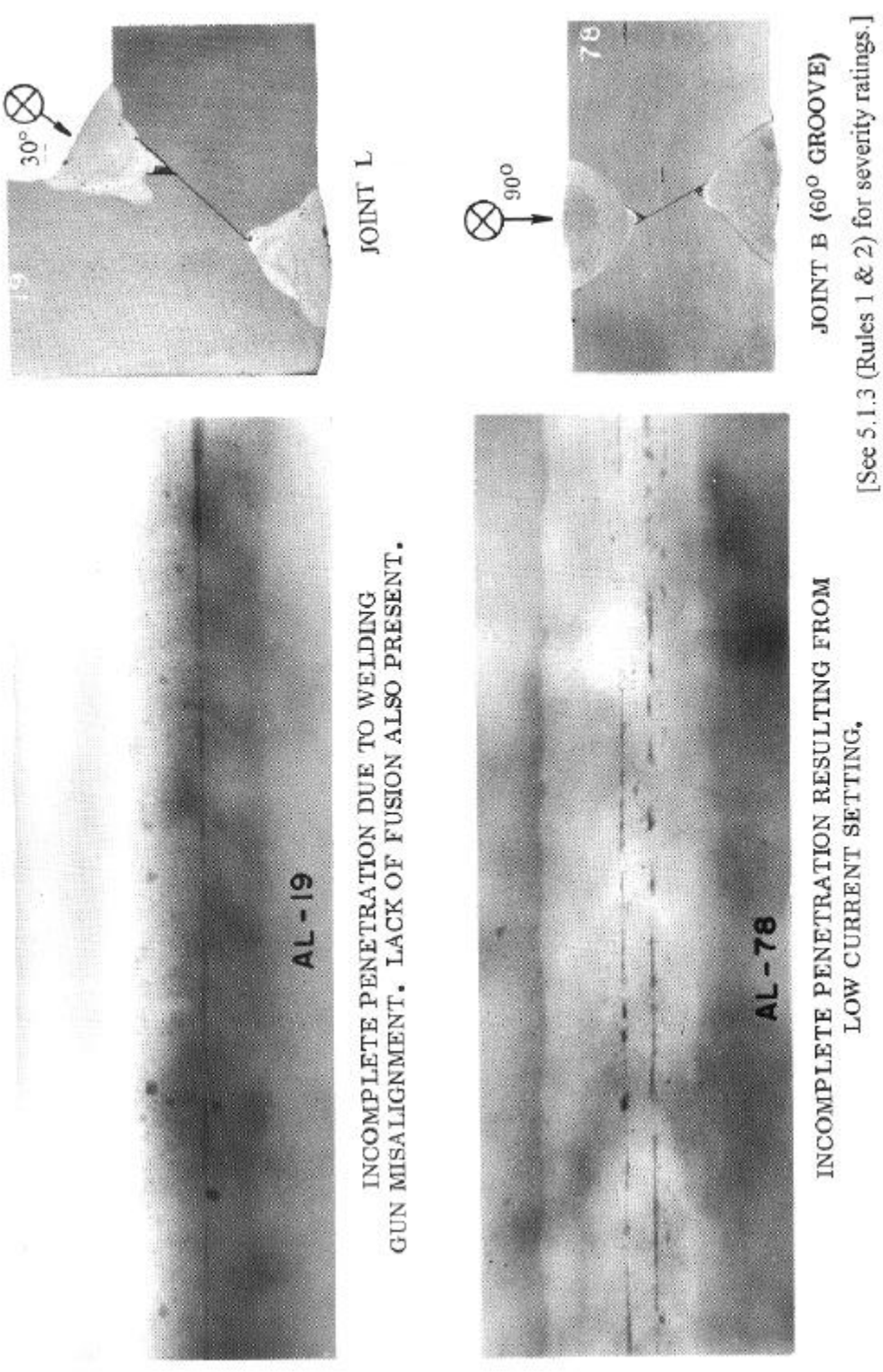


FIGURE 7. Examples of incomplete penetration correlated with weld cross section in aluminum welds.

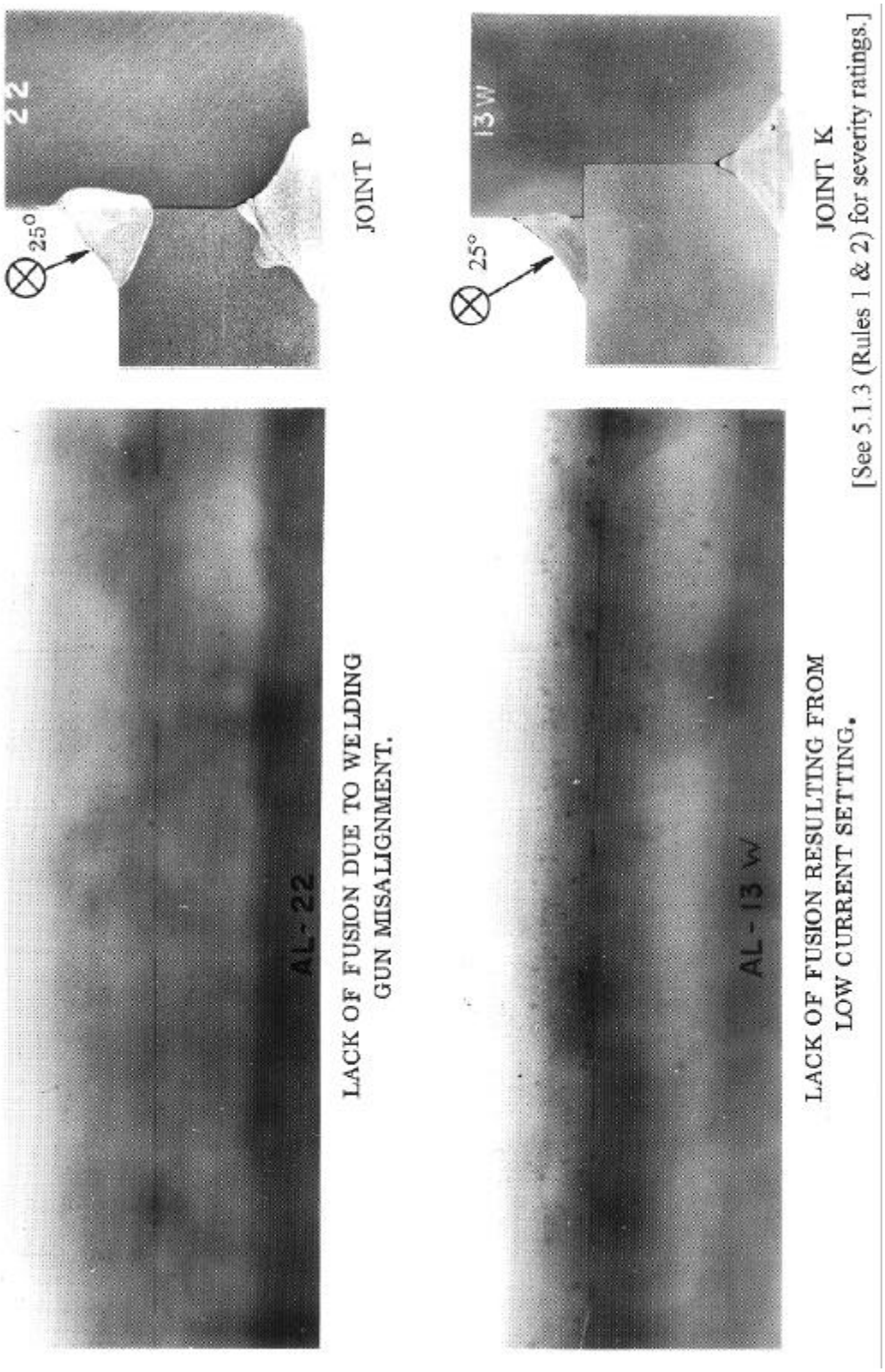


FIGURE 8. Examples of lack of fusion correlated with weld cross section in aluminum welds.

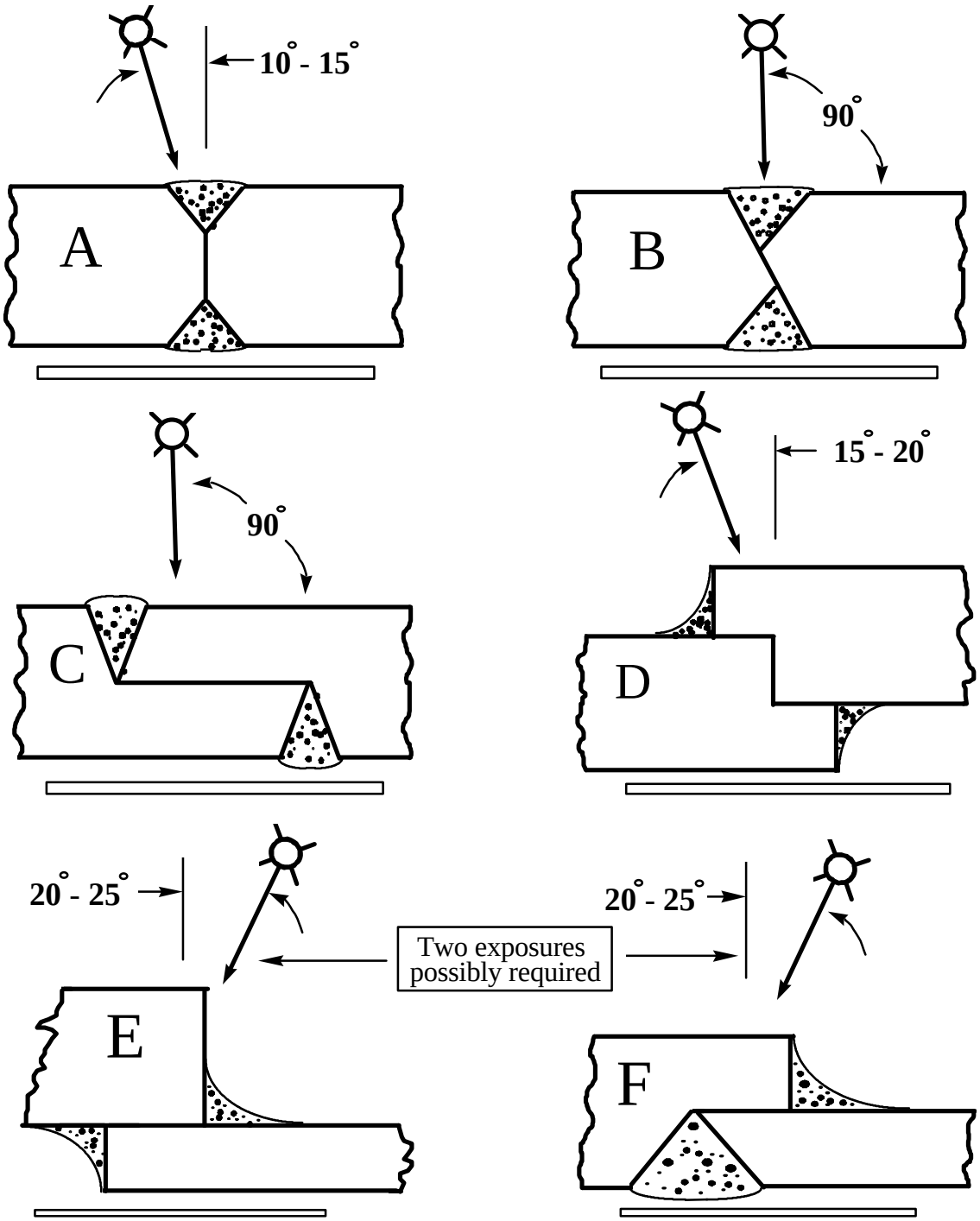


FIGURE 9. Recommended angle beam and film location for typical partial-penetration joints.

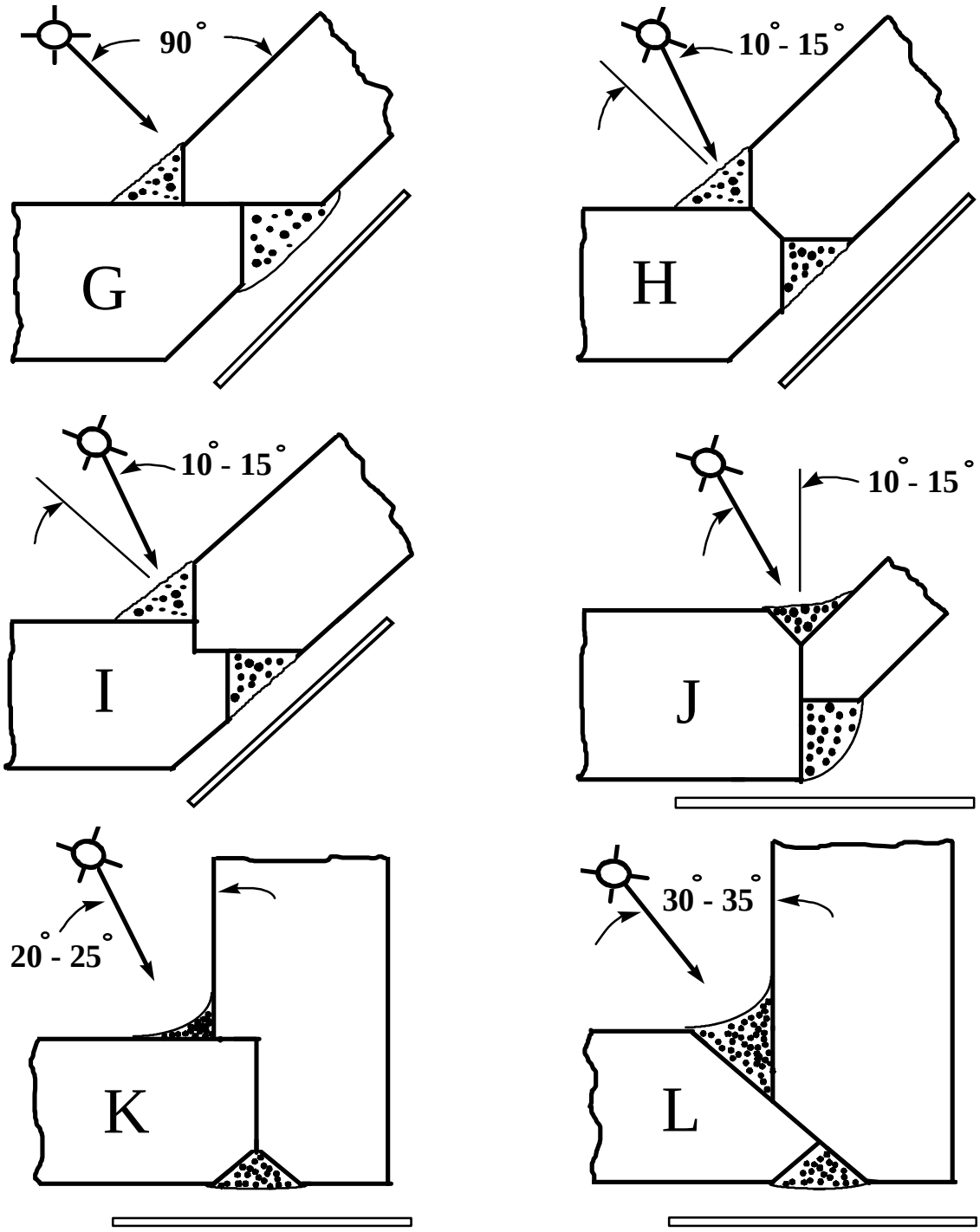


FIGURE 9. Recommended angle beam and film location for typical partial-penetration joints - Continued.

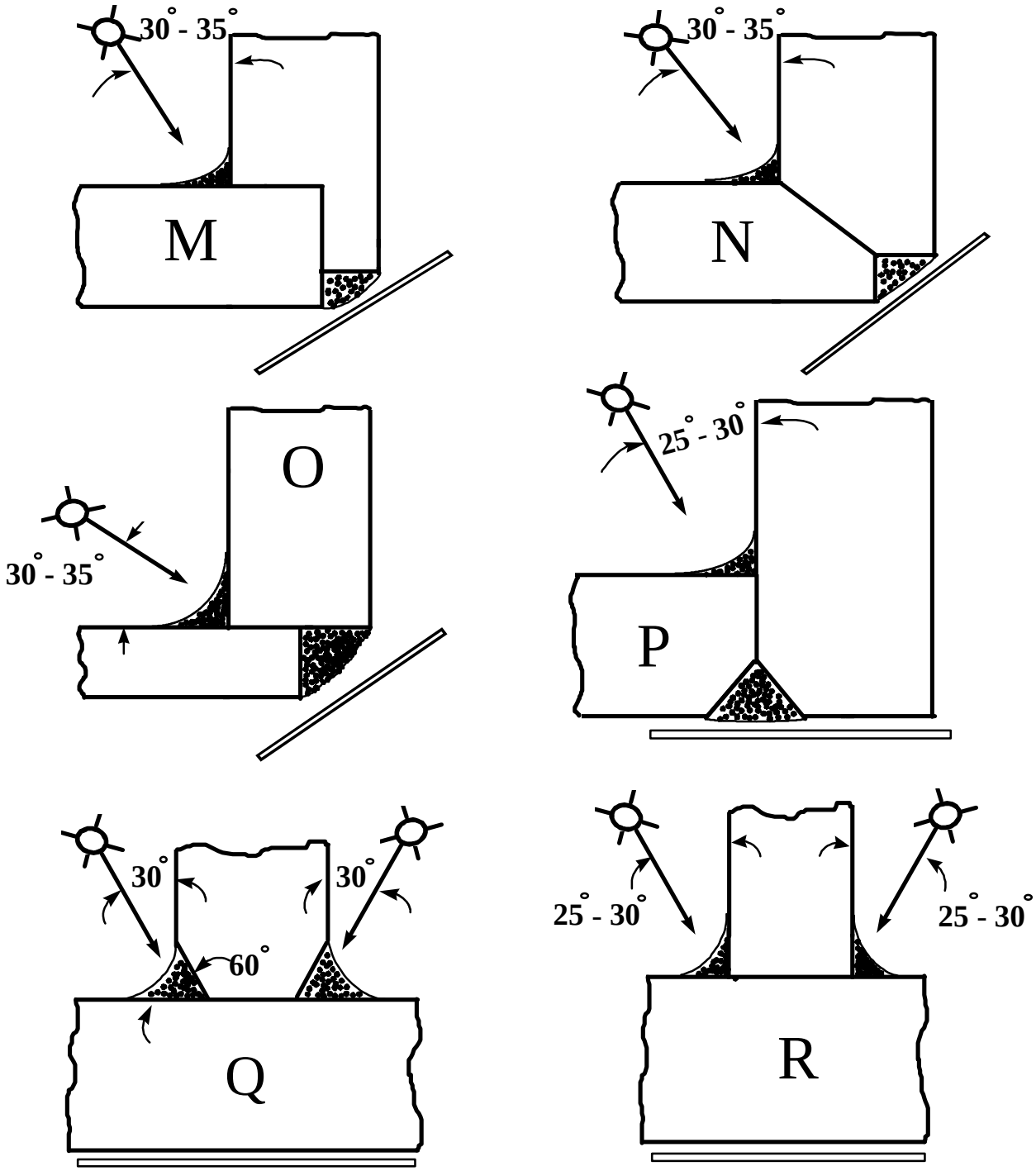


FIGURE 9. Recommended angle beam and film location for typical partial-penetration joints - Continued.

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(Project NDTI-0266)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-STD-1895B(AT)	2. DOCUMENT DATE *(YYMMDD)* 980626

3. DOCUMENT TITLE RADIOGRAPHIC REFERENCE STANDARDS AND RADIOGRAPHIC PROCEDURES FOR PARTIAL-PENETRATION ALUMINUM WELDS

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
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c. ADDRESS *(Include Zip Code)* Commander U.S. Army Tank-automotive and Armaments Command ATTN: AMSTA-TR-E/BLUE Warren, MI 48397-5000	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403 Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340