



American Welding Society

The Practical
Reference Guide for

Radiographic Inspection

Acceptance Criteria

THE PRACTICAL REFERENCE GUIDE for RADIOGRAPHIC INSPECTION ACCEPTANCE CRITERIA

**Located, reviewed and reformatted under the
AWS Product Development Committee as a service
for quality-minded welding fabricators.**

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FOREWORD

A US military standard (MIL-STD-2035), in use for more than twenty years, set forth acceptance criteria for welds evaluated by nondestructive examination. As a military standard, those acceptance criteria could be applied as standards for fabrications for military use. It is recognized that certain nonmilitary fabrications might also benefit from comparison with these criteria. Although these criteria, offered herein, do not constitute a consensus standard of the American Welding Society, they are made available by AWS for consideration by fabricators.

A technical committee of AWS is currently evaluating these acceptance criteria with a view to possibly producing a consensus standard, but that evolution is not complete at this time. Should it be completed and result in an AWS standard, this document will be withdrawn in favor of the resulting standard.

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1.0 SCOPE

Three classes of radiographic quality are offered for possible application to welds in general fabrication. Normally, the choice of an appropriate quality level is made by the engineer, the user or may be contained in the contractual documents. Among the possibilities are the quality levels shown in this document, however, other choices may also be appropriate.

2.0 DEFINITIONS

The definitions of the identified discontinuities are contained in AWS A3.0, Standard Welding Terms and Definitions. Specific terms not included in AWS A3.0 are clarified below.

2.1 Crater Pit. An approximately circular surface condition extending into the weld in an irregular manner caused by insufficient filler metal at the weld stop.

2.2 Incomplete Consumable Insert Melting. Melting of the consumable insert without fusion to the base metal along either side of the consumable insert.

2.3 Oxidation. A condition resulting from partial or complete lack of inert gas shielding of a surface which is heated during welding, resulting in formation of oxide on the surface. This condition may range from slight oxidation evidenced by a multicolored or tightly adhering black film, to the extreme of a very rough surface having a crystalline, or "sugared" appearance.

2.4 Root Surface Center-line Crease or Shrinkage. An intermittent or continuous center-line concavity formed on the root surface.

3.0 RADIOGRAPHIC INDICATIONS

3.1 General

3.1.1 Radiographic Technique. Radiographic technique is usually required to be in accordance with some applicable standard for nondestructive testing requirements. To properly evaluate radiographic indications in welds, the film reviewer should be sure that the correct film has been used and has been developed according to the manufacturer's specifications. Any film conditions such as density, penetrometer location and identification, and extraneous artifacts should be evaluated by the film reviewer.

3.1.2 Cracks. Welds containing any crack are usually rejected.

3.1.3 Burn Through, Melt Through and Crater Pit. Burn through, melt through and crater pits are usually accepted provided the areas do not contain cracks, crevices or globules and provided the convexity or concavity limits otherwise specified are not exceeded.

3.1.4 Tungsten Inclusions. Tungsten inclusions having a maximum dimension greater than 20% of the design material thickness or 1/8 inch, whichever is less, are usually rejected. Smaller tungsten inclusions are generally counted as porosity.

3.1.5 Questionable Indications. When doubt exists as to whether an indication on the radiograph is the result of surface imperfections or subsurface defects, it is common practice to compare the radiograph with the weld. If the indication in question is the result of an acceptable surface imperfection and does not interfere with interpretation, that weld may be accepted.

3.1.6 Slag, Incomplete Fusion and Incomplete Joint Penetration Indications

Figures 1 through 3 offer criteria applicable to slag inclusion indications for three classes of weld radiographic quality. Figures 4 and 5 offer criteria applicable to indications of incomplete fusion and incomplete joint penetration for three classes of weld radiographic quality.

a. General. Indications having a maximum size of 1/8 inch may be evaluated as slag or porosity, usually whichever is less restrictive. A cluster or a group of aligned indications including both slag and porosity are usually evaluated as either all slag or all porosity.

b. Aligned Indications. A group of four or more indications is usually considered aligned when a straight line through the geometric center of the two outer indications touches the intervening indications, and said line lies axially with the welded seam within approximately 5°.

- (1) Multiple aligned slag indications separated in any one direction from adjacent groups or individual indications by L^* or 1/2 inch, whichever is less, are usually acceptable.
- (2) Indications separated in any direction from adjacent groups or individual indications by L^* or 1/2 inch, whichever is less, are usually acceptable.

* L is defined as the length of the longer indication being evaluated.

c. Unaligned Indications. Unaligned indications are generally two or more indications that do not meet the aligned criteria of 3.1.6(b).

3.1.7 Porosity

Figure 6 offers criteria applicable to cluster porosity indications for various thicknesses of base metals. Figures 7 through 24 offer criteria applicable to scattered porosity indications for various thicknesses of base metals and three classes of weld radiography quality.

a. General. Porosity indications 1/64 inch or less in diameter are usually not counted in evaluation of weld radiographic quality.

b. Clustered Porosity. Porosity are usually considered as clustered when a group of four or more indications are concentrated in a manner as shown in Figure 6. Pores separated from the group by 1/8 inch or 3D (where D is the largest pore in that group), whichever is greater, are not usually considered a part of the group.

c. Randomly Dispersed Porosity. The porosity patterns shown in Figures 7 through 24 are not necessarily the patterns that may appear on the radiographs, but are illustrative of a particular combination of number and size of indications. Acceptance criteria for thicknesses not shown may be extrapolated. For weld lengths less than 6 inches, or weld widths less than shown, the acceptance criteria may be proportionally reduced. Increasing the acceptable pores to compensate for weld widths greater

than that shown in the porosity charts is usually not permitted. When it is considered necessary for evaluation, Figure 25 may be used to determine the total area of acceptable pores for any applicable thickness. When randomly distributed indications occur in a concentrated pattern, but not to such a degree as to be classed as rejectable clusters, these are usually considered rejectable when the concentration in any one inch or more of weld length becomes twice the amount which is shown in the applicable randomly distributed porosity charts.

d. Aligned Porosity. Four or more pores linearly aligned such that the distance between each two adjacent pores is less than D , or $1/16$ inch, whichever is greater, where D is the diameter of the larger of the two adjacent pores, are usually rejected. However, such linearly aligned pores may be acceptable when the total length of the stringer of pores does not exceed the length permitted for a single slag indication. The maximum pore diameter is not usually acceptable if it exceeds the large diameter specified on Figures 7 through 24.

e. Other Indications. Other indications, including clustered, aligned and randomly dispersed indications are usually considered in the evaluation and the total indication area are usually not acceptable if they exceed the basic requirement of $0.01T$ inch per inch or $0.015T$ inch per inch, as applicable.

f. Maximum Pore Diameter. Design material thicknesses equal to or less than $1/8$ inch are usually acceptable if they have no more than six pores in any 6 inch length of weld, and no pores have a diameter greater than 20 percent of the design material thickness. For design material thicknesses greater than $1/8$ inch, an isolated pore may be 25 percent of T or $3/16$, whichever is less, provided that there is not more than one such pore in any 6 inch length.

3.1.8 Oxidation of Root. Rough oxidized surface, accompanied by a wrinkled or "sugared" appearance on the radiograph is not usually acceptable.

3.1.9 Multiple Indications. The presence of the various types of indications on the same radiograph section is usually permitted provided each indication type is within the limits herein except that total accumulated slag usually includes lack of fusion and incomplete penetration indications.

3.1.10 Undercut. External undercut or root undercut is usually evaluated versus the specification limits for visual inspection. Undercut is usually evaluated by visual inspection whenever possible; where this is not feasible, records of use of a workmanship sample or approved measuring system usually accompany the radiographs which exhibit undercut.

3.1.11 Inadvertent Radiography. Inadvertent radiography is defined as the presentation on a required radiograph of adjacent welds or base material which do not require radiography. Acceptance or rejection of indications so revealed is usually based on the following:

a. Base Metal. Any defect revealed by inadvertent radiography is usually evaluated to base metal acceptance criteria; any defect determined to be a crack is usually cause for rejection. For indications other than a crack, if radiography criteria do not exist, an engineering evaluation may be made.

b. Welds Required to be Radiographed. For welds required to be radiographed which are inadvertently radiographed again, any defect revealed by inadvertent radiography is usually evaluated to the original acceptance criteria for that particular weld class.

c. Welds Not Requiring Radiography. For welds which are not required to be radiographed, which are inadvertently radiographed, all defects found are usually evaluated. Defects that are determined to be cracks usually cause the weld to be rejected. Other defects usually call for an engineering evaluation.

Engineering evaluation is usually used to confirm that the structural integrity of the weld or base material is maintained. This evaluation is usually based on the following: performance reliability, prescribed inspection methods and acceptance criteria, and the quality of similar parts which meet the designated inspection requirements. Engineering actions taken in accordance with inadvertently detected defects are usually noted in the radiographic record. Should repairs be required, the repair areas are usually reinspected as originally specified.

3.1.12 Weld and Base Metal Defect Evaluations. Weld spatter, arc strikes, grinding marks, surface roughness or handling marks which may interfere with inspection are usually removed by wire brushing and/or grinding prior to radiography. When weld spatter, arc strikes, etc., are overlooked during visual inspection and are shown as radiographic indications in the base metal not interfering with interpretation of the weld, the affected area need not be reradiographed but the defects are usually removed whenever accessible, visually inspected, and the results noted in the radiographic records. Tool marks or irregular surfaces which are not accessible for removal, such as tool marks on the inside surface of piping adjacent to welds, usually require engineering evaluation, and any technical justification for acceptance may accompany the radiograph.

3.2 Class 1 Weld Radiographic Quality

3.2.1 General. The provisions of Section 3.1 apply where applicable.

3.2.2 Incomplete Fusion and Incomplete Joint Penetration. Welds are usually required to be free of incomplete fusion and incomplete joint penetration indications which exceed the limits of Figure 4. Acceptable incomplete fusion and incomplete joint penetration are usually treated as slag when determining the total accumulated length of slag.

3.2.3 Slag. The maximum single slag length and the maximum accumulation of slag lengths are usually not acceptable if either exceeds that shown in Figure 1.

3.2.4 Porosity

a. Maximum Porosity. The total area of porosity usually permitted, as determined from the radiographic film, is based on one percent of design material thickness "T" per inch of weld being inspected. For calculation, the following formula applies:

Total area of pores permitted in 1 in. length of weld = $0.01T$ in. $\times$ 1 in.

hence, for any six-inch length, the total area of pores usually permitted will be $0.06T$ square inches.

b. Randomly Dispersed Porosity. Randomly dispersed porosity is usually not acceptable if it exceeds the limits of Figures 7 through 16 for weld thicknesses of 1/8 in. to 4 in.

c. Clustered Porosity. Acceptance for clustered porosity, as defined in Section 3.1.7 (d) and as shown in Figure 6, is usually as follows:

Weld Thickness "T"	Maximum Cluster Size Diameter	Maximum Number of Pores
1/4 in. and less	1/4 in.	4, any size
greater than 1/4 in. through 1/2 in.	1/4 in.	No limit, except summation of pore diameters usually may not exceed 1/4 in.
greater than 1/2 in.	1/2T or 3/4 in. whichever is less	No limit, except summation of pore diameters usually may not exceed 1/2T or 3/4 in., whichever is less

In addition, the minimum separation between clusters is usually $4T$ or 3 inches, whichever is less, and the sizes are not usually acceptable if they exceed those shown in Section 3.1.7 (f).

3.2.6 Other Defects

a. Consumable insert welds are usually required to be completely fused to the base material. Incomplete melting may be acceptable if the convexity requirements are met and it can clearly be determined that the insert has been completely fused to the adjacent base metal. The insert is usually considered completely fused to the adjacent base metal if the edges of the insert have flowed, i.e., image of original edge(s) of insert is not present in the radiographic image.

b. The root surface concavity, including centerline shrinkage or wrinkling is usually not acceptable if it exceeds 1/32 inch for welds in pipe less than 2 inch nominal size or 1/16 inch for welds in pipe 2 inch or larger nominal size. Concavity of contour is usually not acceptable unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal. (See Section 3.2.7)

c. The root surface convexity is usually not acceptable if it exceeds 1/16 inch for welds in pipe less than 2 inch nominal size or 3/32 inch for welds in pipe 2 inch or larger nominal size. (See Section 3.2.7)

d. Root concavity or convexity may extend for the entire circumference of the weld.

3.2.7 Verification. Verification of questionable dimensional tolerances is usually established by visual inspection. If this is not feasible, records of use of a workmanship sample or an approved measuring system may be required to accompany the radiographic records.

3.3 Class 2 Weld Radiographic Quality

3.3.1 General. The provisions of Section 3.1 apply where applicable. To properly evaluate radiographic indications in welds, the film reviewer must usually ensure that the correct film has been used and has been developed according to the manufacturer's specifications. Film conditions such as density, penetrometer location and identification, and extraneous artifacts are usually evaluated by the film reviewer.

3.3.2 Incomplete Fusion and Incomplete Joint Penetration. Welds are usually required to be free of incomplete fusion and incomplete joint penetration indications which exceed the limits of Figure 5. Acceptable incomplete fusion and incomplete joint penetration are usually treated as slag when determining the total accumulated length of slag.

3.3.3 Slag. The maximum single slag length and the maximum accumulative slag lengths are usually not acceptable if either exceeds that shown in Figure 2.

3.3.4 Porosity. The provisions of Section 3.2.4 apply where applicable.

3.4 Class 3 Weld Radiographic Quality

3.4.1 General. The provisions of Section 3.1 apply where applicable.

3.4.2 Incomplete Fusion and Incomplete Joint Penetration. Welds are usually required to be free of incomplete fusion and incomplete joint penetration indications which exceed the limits of Figure 5. Acceptable incomplete fusion and incomplete joint penetration are usually treated as slag when determining the total accumulated length of slag.

3.4.3 Slag. The maximum single slag and the maximum accumulative slag length are usually not acceptable if either exceeds that shown in Figure 3.

3.4.4 Porosity. The requirements of Section 3.1.7 usually apply except that the total area of porosity acceptable may be based on the area of porosity being 1.5% of the material thickness in 1 inch length and the randomly dispersed porosity not exceeding the limits of Figures 17 through 24 for weld thicknesses 1/4 inch to 4 inches. Clustered or concentrated porosity may be acceptable provided these indications, when evaluated with other porosity indications, do not exceed the maximum number and size shown in the applicable randomly dispersed porosity chart (or 0.09T square inches) in any six inches of weld.