



American Welding Society®

Pocket Guide for Visual Examination of Welds – Discontinuity Causes and Remedies

Prepared by the B1 Committee on
Methods of Inspection



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Discontinuity Examination and Repair

Visual examination (abbreviation: VT) is the primary method for identifying welding discontinuities. It is fundamental to any effective quality control program. It is also fundamental to assuring weld repair operations are effective and comply with the approved contract documents. For convenience and brevity, all rework and repair activities in this pocket guide are called repairs. As a minimum, various steps in any repair are always examined and evaluated. Welders and inspectors, alike, will examine the repair efforts and compare them with project requirements. Even “close enough” is an evaluation. It has been proven time and time again that integrating quality control actions into fabrication and installation operations reduces labor efforts and repair costs. Early detection of welding discontinuities and other quality failures saves money and time.

While VT is limited only to indications open to the surface and only those indications large enough to be visible to the eye, it is a very effective method for detecting cracks and other damaging discontinuities. Effective use of flashlights and magnifying lenses enables inspectors to identify indications as small as 0.01 in [0.25 mm]. Liquid penetrant (PT) and magnetic particle (MT) examinations can also be performed to augment visual examination. The dyes or colored particles used in these nondestructive examination (NDE) methods are specially designed to cluster around surface discontinuities making detection and evaluation easier. They are often used in-process to help determine the extent of the discontinuity and to assure that it has been sufficiently removed. Other volumetric examination NDE methods such as radiographic (RT) and ultrasonic (UT) examinations can be used to verify subsurface weld quality after repair. For more information on NDE methods and techniques, see AWS B1.10/B1.10M, *Guide for the Nondestructive Examination of Welds*. Formal

AWS definitions for most discontinuities discussed in this pocket guide can be found in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*.

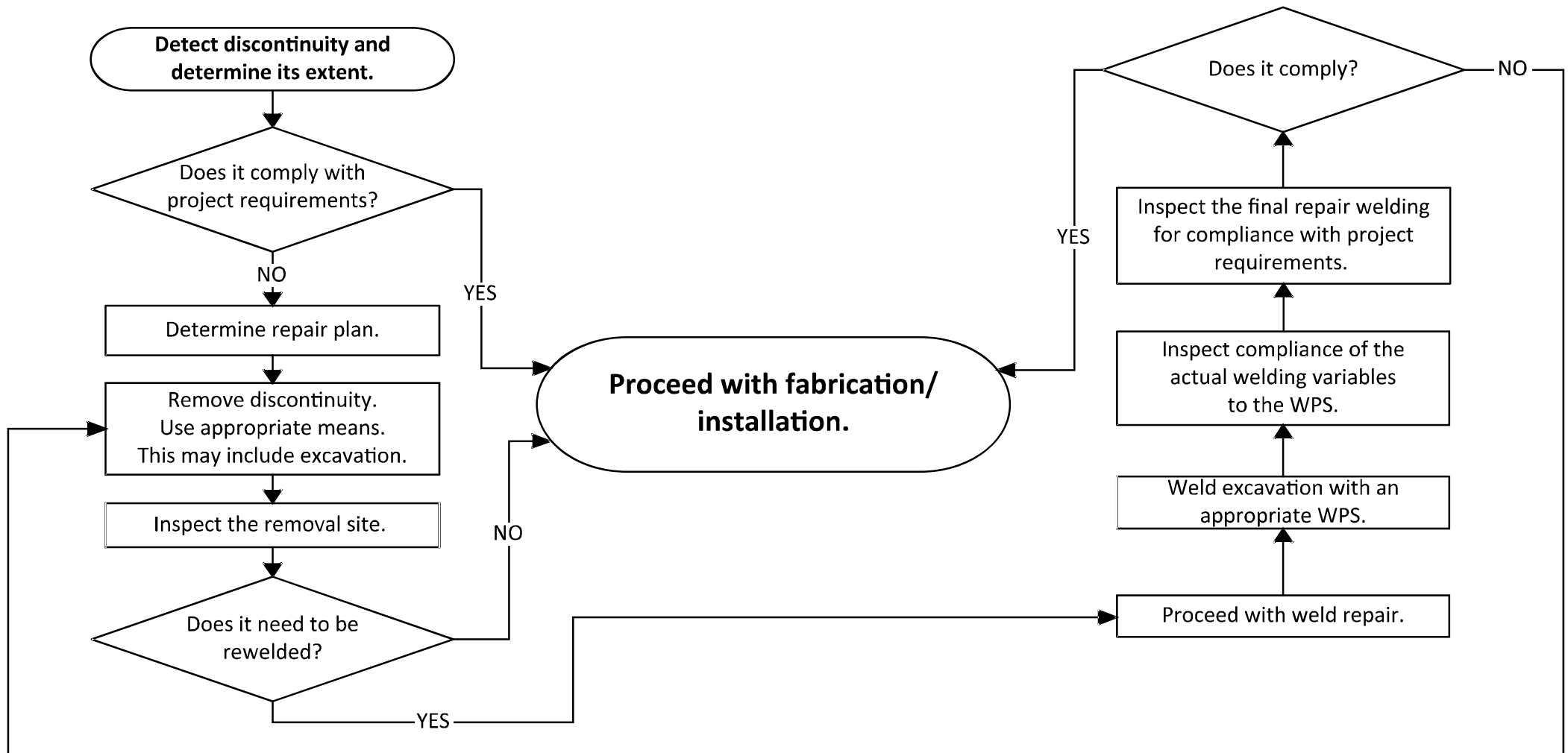
The emphasis of this pocket guide is on the detection and repair of physical weld discontinuities found in common arc welding processes. Often, however, the root cause of the discontinuity is the failure to follow the applicable welding procedure specification (WPS). The WPS is a vital welding control document used throughout the welding industry. Its improper application can impact the physical, mechanical, or chemical properties of the weldment and become an “unseen” quality issue. For this reason, it is important to weld within the limits of an appropriate welding procedure specification. Best practices expect the welding parameters to be monitored during repair operations.

Repairs cannot be completely eliminated using the welding processes described in this pocket guide. The remedies presented here only cover manual, semi-automatic, and mechanized arc welding processes. However, weld repairs can be minimized through early VT by welders and inspectors. In the event of cracks, MT and PT will clearly show welding personnel that excavation efforts have completely removed the discontinuity. Once a non-complying weld discontinuity is identified, the repair sequence generally involves the same decisions. The following flowchart shows a typical weld repair operation.

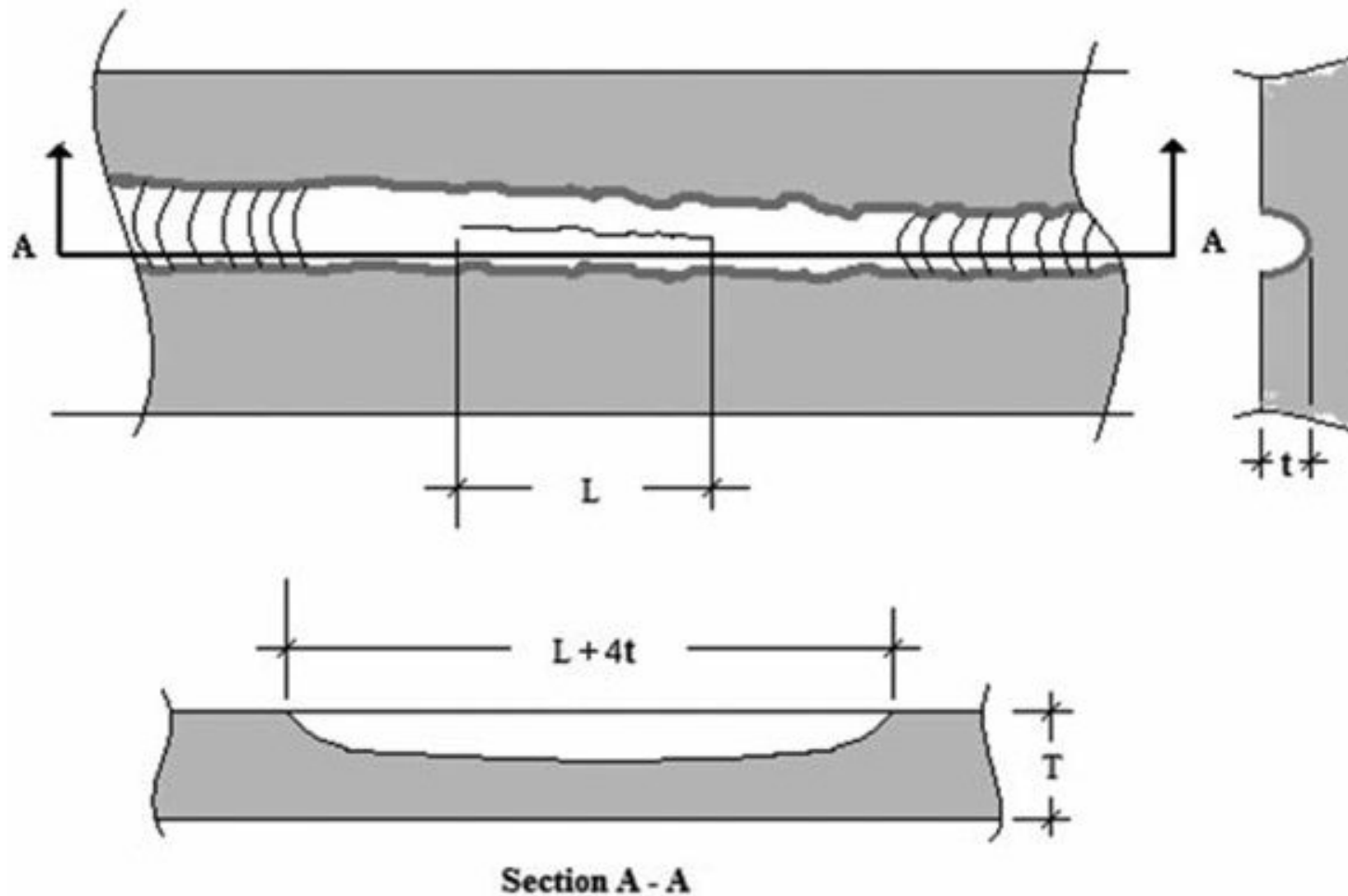
There are no fast and hard rules for making repair excavations, except one: **The Excavation Must Be Properly Prepared Before You Start Welding.**

It is important that the discontinuity be completely removed. Tapering out of the bottom of the excavation, slightly beyond the ends to a “boat-shaped” excavation, will make final repair welding easier. The figure on page 5 illustrates a typical excavation. Here, the end-tapers are twice the weld thickness. Other excavation contours may be necessary or more efficient. It is important that the final excavation essentially conform with a U-Groove joint configuration. A good repair excavation is clean, permits full electrode manipulation at its bottom, and has edges wider at the top than at the bottom.

Typical Repair Sequence



Typical “Boat-Shaped” Excavation

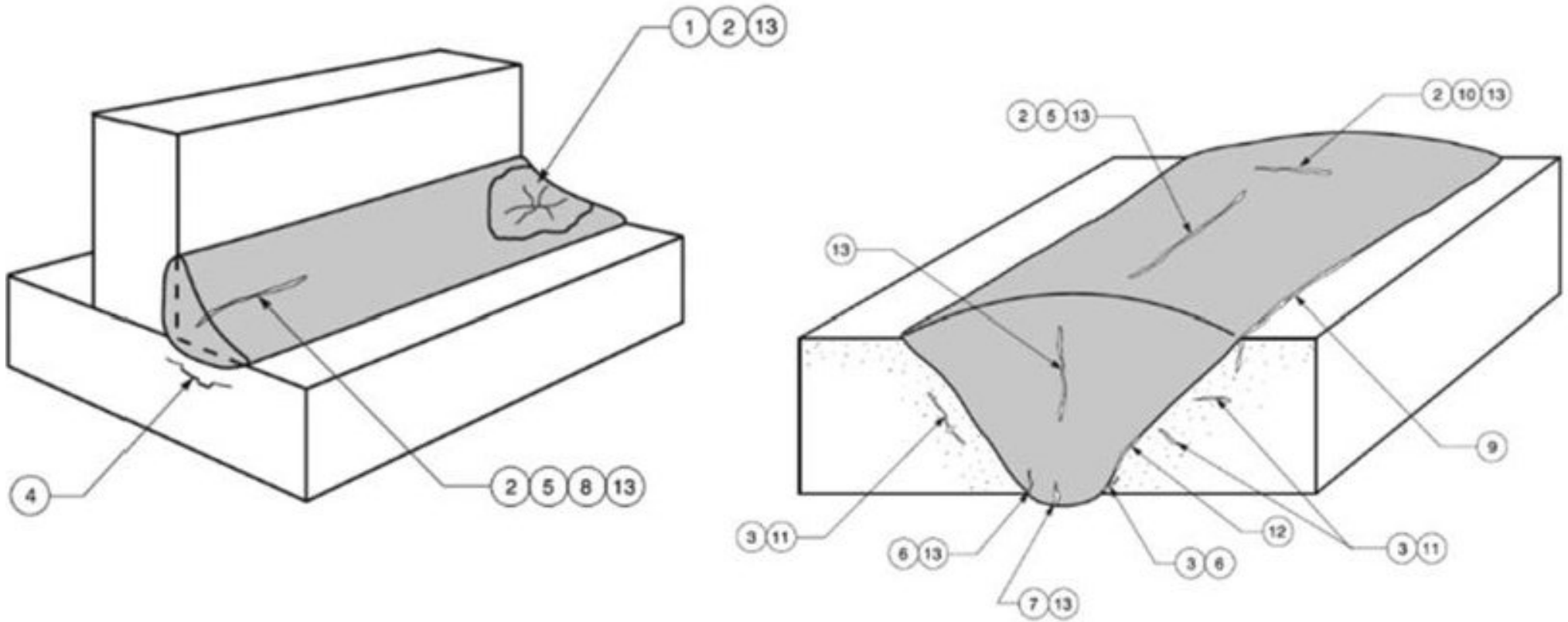


Cracks

Cracks are fracture-type discontinuities characterized by a sharp tip and a high ratio of crack length to its width, or opening displacement. Cracks are generally considered the most severe discontinuity because of their tendency to propagate under stress, or run. Cracks can be further described by their location, their geometry, time of occurrence, or service conditions. The figure illustrates common crack terminology and the following table lists some common causes and remedies.

Crack Legend

- | | |
|-----------------------------|--------------------------|
| 1) Crater Crack | 8) Throat Crack |
| 2) Face Crack | 9) Toe Crack |
| 3) Heat-Affected Zone crack | 10) Transverse Crack |
| 4) Lamellar Tear | 11) Underbead Crack |
| 5) Longitudinal Crack | 12) Weld Interface Crack |
| 6) Root Crack | 13) Weld Metal Crack |
| 7) Root Surface Crack | |



Crack Types

Common Causes and Remedies of Cracking

Causes	Remedies
High joint restraint	• Use low-hydrogen, ductile weld filler metal. • Preheat joint to promote the escape of interstitial hydrogen from the weld zone. • Weld from the most restrained portion of the joint to the least restrained. Allow the ends to move freely as long as possible. • Peen initial weld passes to mechanically relieve local residual stresses. • Increase weld bead thickness when the size of the root and initial weld passes are small compared to the mass of base metal. • Avoid concave stringer weld beads.
High carbon steels	• Preheat joint when carbon equivalent approaches 0.45 and greater to slow down the weld cooling rate. • Preheat joint to promote the exhaust of interstitial hydrogen trapped in the cooling weld bead.
Poor joint preparation & fit-up	• Prepare groove weld joints to provide uniform root gaps and root faces. • Build up excessive gaps and excessive gouges before fit-up. • Dress the reworked joint contour for welding.