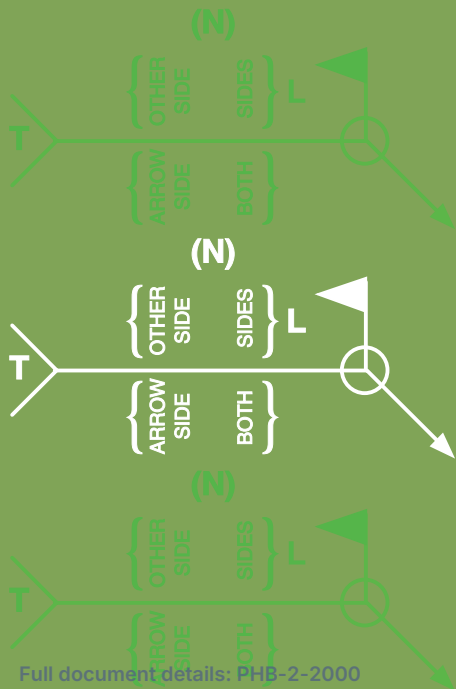




The Everyday Pocket Handbook for Visual Inspection and Weld Discontinuities—Causes and Remedies



Number 2 in a series

Compiled as a useful tool for on-the-job welding personnel by the AWS Product Development Committee

(Edited by Ted V. Weber, Principal Consultant, Weber & Associates)

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Basic Safety Precautions

Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpiece should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Avoid breathing the air in the fume plume directly above the arc. Do not weld in a confined area without a ventilation system. Use point-of-welding fume removal when welding galvanized steel, zinc, lead, cadmium, chromium, manganese, brass, or bronze. Do not weld on piping or containers that have held hazardous materials unless the containers have been inerted properly.

Compressed Gas Cylinders. Keep caps on cylinders when not in use. Make sure that gas cylinders are chained to a wall or other structural support.

Radiation. Arc welding may produce ultraviolet, infrared, or light radiation. Always wear protective clothing and eye protection to protect the skin and eyes from radiation. Shield others from light radiation from your welding operation.

AWS also recommends a personal copy of “Arc Welding Safely”, “Fire Safety in Welding and Cutting”, and “Safety in Welding, Cutting, and Allied Processes”.

Visual Inspection Notes

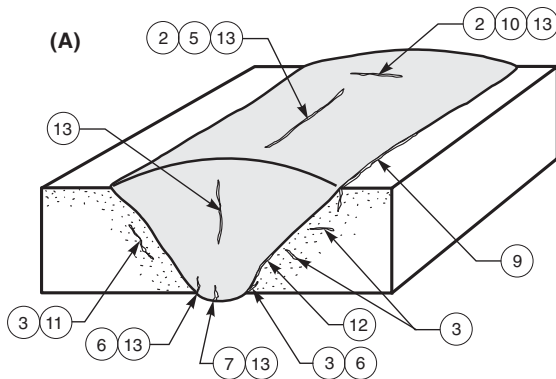
Visual Inspection is a very effective inspection method, and it should be the primary method included in any effective Quality Control Program. It has been shown repeatedly that, **“Visual inspection, conducted by properly trained inspectors, results in the discovery of the vast majority of those defects which would only be discovered later by some more expensive nondestructive test method.”** While visual inspection is limited to materials’ surface-only examination, it often detects the most damaging defects. Visual inspection [abbreviated **“VT”** by the American Society for Nondestructive Testing (ASNT)] of welded components requires inspectors to have a broad knowledge of many technologies, including welding, destructive testing, non-destructive testing, and metallurgy, as well as the correct terminology for each.

It is important to distinguish between the words ‘discontinuity’ and ‘defect’. Discontinuity refers to **“An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics; a discontinuity is not necessarily a defect.”** A defect refers to **“A condition, or conditions, that render a part unable to meet applicable minimum acceptance standards or specifications.”** All defects are discontinuities, but not all discontinuities are defects. A defect can be considered a ‘rejectable discontinuity’.

This pocket handbook provides a convenient source for the most common base metal and weld metal discontinuities found by effective VT. The handbook is arranged by discontinuity type, including applicable VT detection methods, and likely causes and remedies in addition to suggested repair methods.

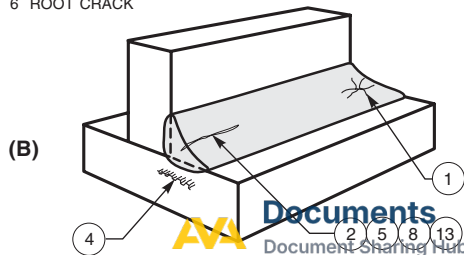
Cracks

A crack is defined as “**A fracture type discontinuity characterized by a sharp tip and a high ratio of length and width to opening displacement.**” Cracks are usually considered the most severe discontinuity because of their tendency to propagate under stress. Cracks are usually further described by their location geometry, time of occurrence, or common usage terms; see figure below for AWS crack terminology.



LEGEND:

- | | |
|----------------------------|-------------------------|
| 1 CRATER CRACK | 7 ROOT SURFACE CRACK |
| 2 FACE CRACK | 8 THROAT CRACK |
| 3 HEAT-AFFECTED ZONE CRACK | 9 TOE CRACK |
| 4 LAMELLAR TEAR | 10 TRANSVERSE CRACK |
| 5 LONGITUDINAL CRACK | 11 UNDERBEAD CRACK |
| 6 ROOT CRACK | 12 WELD INTERFACE CRACK |
| | 13 WELD METAL CRACK |



Types of cracks often include the following prefixes: base metal, cold, crater, delayed, face, heat-affected zone, hot, hydrogen, intergranular, lamellar tear, longitudinal, quench, root, service induced, stress corrosion, throat, toe, transgranular, transverse, underbead, weld metal, and others.

Crack detection can be achieved visually if the crack is present on the surface and is of sufficient size to be visible to the eye. Smooth, clean surfaces, oblique angle lighting, and a 10x power magnifier are extremely helpful during visual inspection for surface cracking. If the surface cracking cannot be found visually, the next step is the use of the Penetrant Test method (PT). Magnetic Particle Testing (MT) can also be used, but is limited to testing magnetic base materials. Ultrasonic Testing (UT), Eddy Current Testing (ET), and Radiographic Testing (RT) are required for the detection of subsurface cracking. Refer to the *AWS Welding Inspection Technology* materials for more details regarding PT, MT, UT, ET, and RT.

Cracking can be caused by a multitude of conditions, but the more common causes are: embrittlement of the base or weld metal caused by too-rapid cooling and the formation of brittle martensite, weld shrinkage stresses, insufficient root bead size, poor joint design, nonmatching filler metals, and corrosive environment. See following chart for specific causes and recommended remedies.

Repairs to cracks include the following general requirements:

1. Locate crack extent and orientation.
2. Grind to remove completely; confirm with NDT. *Do not weld over (on top of) cracks.*
3. Weld using proper procedure, including preheat if required, use small diameter electrodes and stringer bead progression.
4. NDT finished weld and base metal.

Note: The above procedures may not result in a suitable repair of stress corrosion cracking, which may require replacement of the affected part or parts.

Common Causes and Remedies of Cracking	
Causes: Weld Metal Cracking	Remedies: Weld Metal Cracking
Highly rigid joint	Preheat Relieve residual stresses mechanically (peening) Minimize shrinkage stresses using backstep or block welding sequence
Excessive dilution	Change welding current and travel speed Weld with covered electrode negative; butter the joint faces prior to welding
Defective electrodes	Change to new electrode; bake electrodes to remove moisture
Poor fit-up	Reduce root opening; build up the edges with weld metal. Increase root opening.
Small weld bead	Increase electrode size; raise welding current; reduce travel speed
High sulfur base metal	Use filler metal low in sulfur
Angular distortion	Change to balanced welding on both sides of joint
Crater cracking	Fill crater before extinguishing the arc; use a welding current decay device when terminating the weld bead
Causes: Heat-Affected Zone	Remedies: Heat-Affected Zone
Hydrogen in welding atmosphere	Use low-hydrogen welding process; preheat and hold for 2 hour after welding or postweld heat treat immediately
Hot cracking	Use low heat input; deposit thin layers; change base metal and/or filler metal
Low ductility	Use preheat; anneal base metal prior to welding
High residual stresses	Redesign weldment; change welding sequence; apply intermediate stress-relief heat treatment
High hardenability	Preheat; increase heat input; heat treat without cooling to room temperature
Brittle phases in the microstructure	Solution heat treat prior to welding

Inclusions

Inclusions are defined as **“Entrapped foreign solid material, such as slag, flux, tungsten, or oxide.”** The inclusions may be found as single particles, aligned particles, or clustered particles. Slag inclusions are frequently found on the weld surfaces, or along the toes of the weld due to improper cleaning techniques. Tungsten inclusions are usually subsurface. Examples of inclusions are shown below. Inclusions on the surface can be detected by VT; subsurface inclusions require UT or RT.



Slag Inclusions (darkened areas)

Repairs of inclusions on the surface require removal by gouging or grinding, welding if required, and reinspection by appropriate NDT method. Subsurface inclusions require removal by gouging or grinding, followed by weld repair and reinspection.

Common Causes and Remedies of Slag Inclusions

Causes	Remedies
Failure to remove slag	Clean surface and previous weld bead
Entrapment of refractory oxides	Power wire brush the previous weld bead
Tungsten in the weld metal	Avoid contact between the electrode and the work; use larger electrode
Improper joint design	Increase groove angle of joint
Oxide inclusions	Provide proper gas shielding
Slag flooding ahead of the welding arc	Reposition work to prevent loss of slag control
Poor electrode manipulative technique	Change electrode or flux to improve slag control
Entrapped pieces of electrode covering	Use undamaged electrodes



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