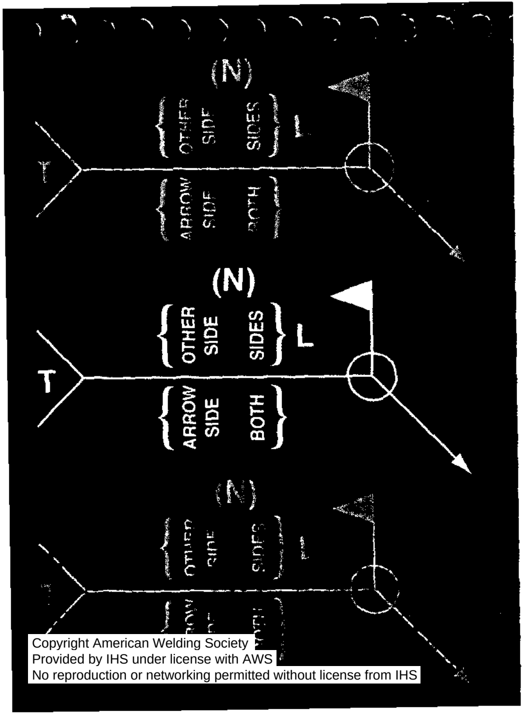


$12

# 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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**NOTE:** Although care was taken in choosing and presenting the data in this guide, AWS cannot guarantee that it is error free. Further, this guide is not intended to be an exhaustive treatment of the topic and therefore may not include all available information, including with respect to safety and health issues. By publishing this guide, AWS does not insure anyone using the information it contains against any liability or injury to property or person arising from that use.

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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, nondestructive testing, and metallurgy, as well as the correct terminology for each.

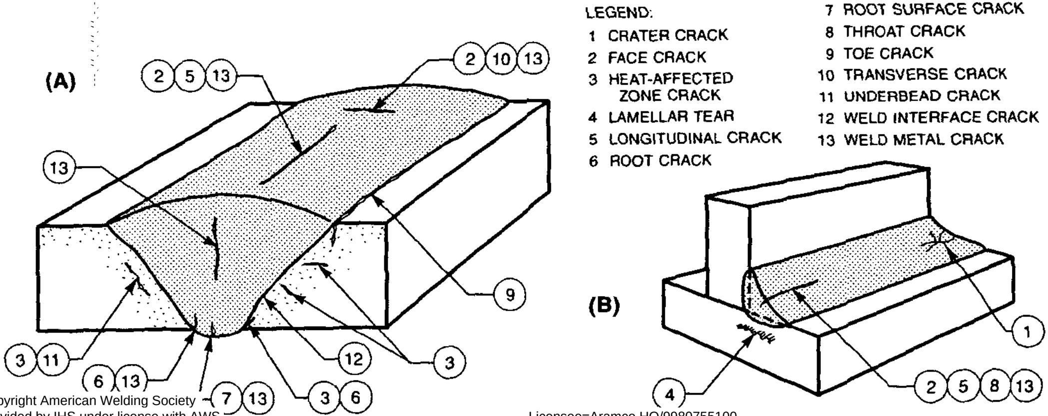


It is important to distinguish between the words 'discontinuity' and 'defect'. Discontinuity refers to "**An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics; a discontinuity is not necessarily a defect**." 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.



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:

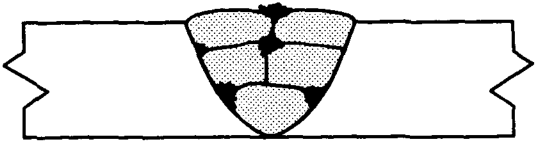
1. Locate crack extent and orientation.
2. Grind to remove completely; confirm with NDT. *Do not weld over (on top of) cracks.*
3. Weld using proper procedure, including preheat if required, use small diameter electrodes and stringer bead progression.
4. NDT finished weld and base metal.

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<br>Relieve residual stresses mechanically (peening)<br>Minimize shrinkage stresses using backstep or block welding sequence |
| Excessive dilution | Change welding current and travel speed<br>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 |
| [illegible] | Preheat; increase heat input; heat treat without cooling to room temperature |
| ...structure | Solution heat treat pri... |

# 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.



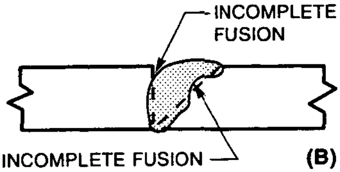
**Slag Inclusions (darkened areas)**

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.

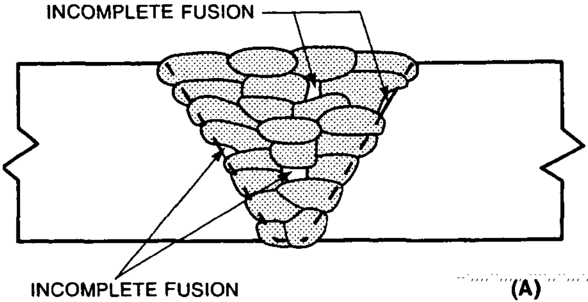
| Common Causes and Remedies of Slag Inclusions | |
|---|---|
| **Causes** | **Remedies** |
| Failure to remove slag | Clean surface and previous weld bead |
| Entrapment of refractory oxides | Power wire brush the previous weld bead |
| Tungsten in the weld metal | Avoid contact between the electrode 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 |

# Incomplete Fusion

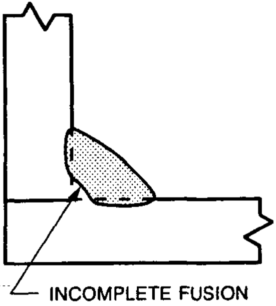
Incomplete fusion is defined as "**A weld discontinuity in which fusion did not occur between weld metal and fusion faces or adjoining weld beads**." Incomplete Fusion (IF) can occur on both groove welds and fillet welds. The term specifically applies to fillet welds where the weld does not extend to the joint root. See the figures below.




(B)




(A)




(C)

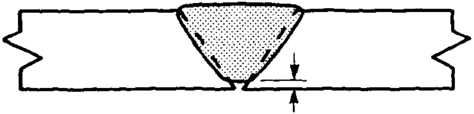
Detection of incomplete fusion using VT is possible if the discontinuity location is visible on the surface; oblique angle lighting and 10x magnification aid the inspector. Generally, IF is subsurface and is found using UT or RT methods.

Repairs of incomplete fusion require removal of the discontinuity by gouging or grinding, followed by weld repair and final inspection.

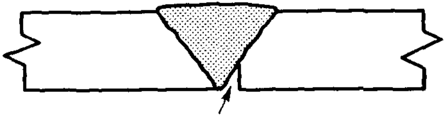
| **Common Causes and Remedies of Incomplete Fusion** | |
|---|---|
| **Causes** | **Remedies** |
| Insufficient heat input, wrong type or size of electrode, improper joint design, or inadequate gas shielding | Follow correct welding procedure specification |
| Incorrect electrode position | Maintain proper electrode position |
| Weld metal running ahead of the arc | Reposition work, lower current, or increase weld travel speed |
| Trapped oxides or slag on weld groove or weld face | Clean weld surface prior to welding |

# Incomplete Joint Penetration

Incomplete joint penetration is defined as "**A joint root condition in a groove weld in which weld metal does not extend through the joint thickness.**" *Note that it applies to groove welds only, not fillet welds.* Examples of incomplete joint penetration (IJP) are shown in the following figures.



INCOMPLETE JOINT PENETRATION



INCOMPLETE JOINT PENETRATION

Incomplete joint penetration can easily be found by VT if the root of the groove weld is visible; oblique angle lighting assists in its detection. For groove welds with the root not visible, UT or RT are required for detection.

Repairs for IJP, when access to the root of the groove weld is possible:

1. Gouge or grind root to an oval, open shape, permitting access to root.
2. Weld, followed by appropriate NDT method.

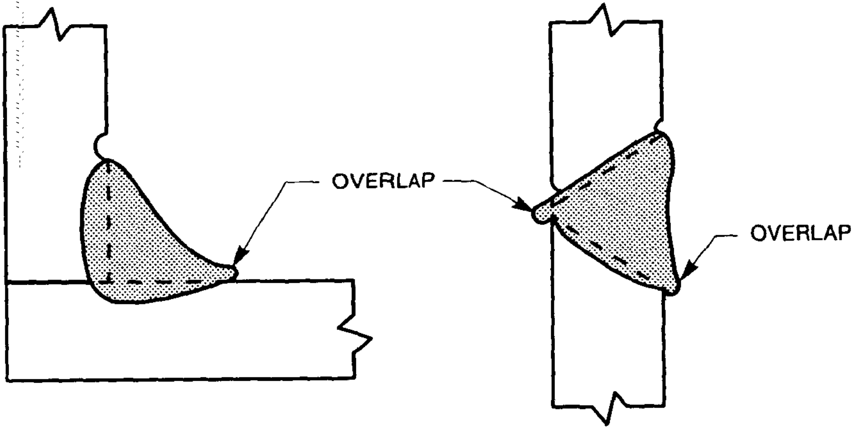
Repairs for IJP, where access to the root is not possible:

1. Gouge or ground from the weld face to remove entire weld down to joint root.
2. Weld, followed by appropriate NDT method.

| Common Causes and Remedies of Incomplete Joint Penetration | |
|---|---|
| **Causes** | **Remedies** |
| Excessively thick root face or insufficient root opening | Use proper joint geometry |
| Insufficient heat input | Follow welding procedure specification |
| Slag flooding ahead of welding arc | Adjust electrode or work position |
| Electrode diameter too large | Use smaller electrodes in root or increase root opening |
| Misalignment of second side weld | Improve visibility or backgouge |
| Failure to backgouge when specified | Backgouge to sound metal if required in welding procedure specification |
| Bridging or root opening | Use wider root opening or smaller electrode in root pass |

# Overlap

Overlap is defined as "**The protrusion of weld metal beyond the weld toe or weld root**." Examples are shown below for fillet and groove welds.



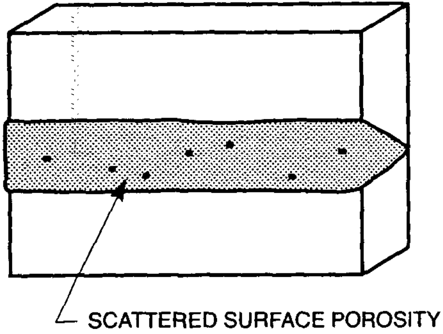
Detection of overlap is usually found by VT if the surfaces are visible to the eye; oblique lighting and 10x magnification are helpful. PT and MT may be required to inspect questionable areas.

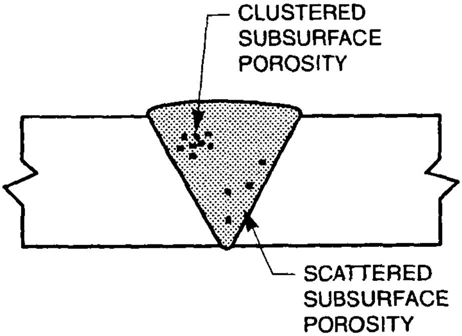
Repairs include removal of overlap by gouging or grinding as a minimum, and may require weld repairs to the gouged or ground areas, followed by reinspection using appropriate NDT method.

| **Common Causes and Remedies of Overlap** | |
|---|---|
| **Causes** | **Remedies** |
| Slow travel speed | Increase travel speed |
| Poor electrode manipulation | Additional welder training |
| Gravity effects | Additional welder training |

# Porosity

Porosity is defined as "**Cavity-type discontinuities formed by gas entrapment during solidification or in a thermal spray deposit**." The porosity may be surface or subsurface, a single cavity, aligned, or clustered, and is represented by the following figures.



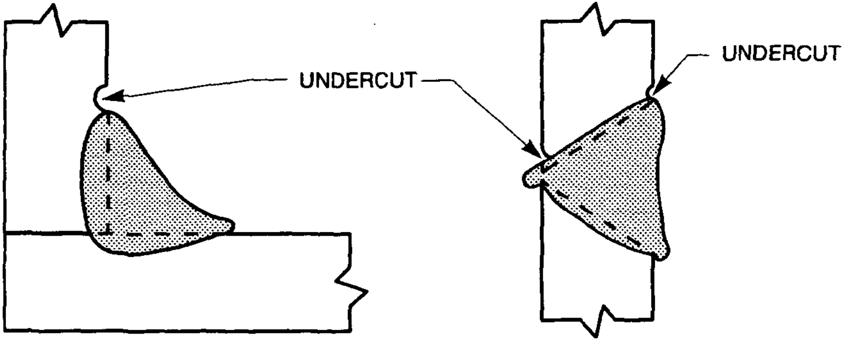

Repairs of porosity consist of removal of the affected area by gouging or grinding, weld repair, followed by reinspection by the appropriate NDT method.

## Common Causes and Remedies of Porosity

| Causes | Remedies |
|---|---|
| Excessive hydrogen, nitrogen, or oxygen in welding atmosphere | Use low-hydrogen welding process; filler metals high in deoxidizers; increase shielding gas flow |
| High solidification rate | Use preheat or increase heat input |
| Dirty base metal | Clean joint faces and adjacent surfaces |
| Dirty filler wire | Use specially cleaned and packaged filler wire, and store it in clean area |
| Improper arc length, welding current, or electrode manipulation | Change welding conditions and techniques |
| Volatization of zinc from brass | Use copper-silicon filler metal; reduce heat input |
| Galvanized steel | Remove zinc prior to welding<br>Use E6010 electrodes and manipulate the arc heat to volatilize the zinc ahead of the molten weld pool |
| Excessive moisture in electrode covering or on joint surfaces | Use recommended procedures for baking and storing electrodes<br>Preheat the base metal |
| | Use electrodes with basic slagging reactions |

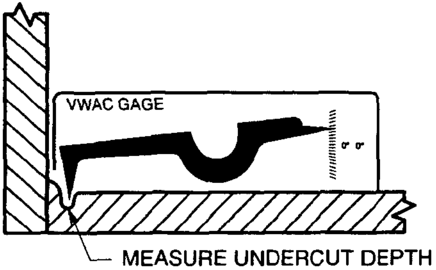
# Undercut

Undercut is defined as "**A groove melted into the base metal adjacent to the weld toe or weld face and left unfilled by weld metal**." Examples are shown in the following figures.




Detection of surface undercut is easily found by VT using oblique lighting. 'Catching a thumbnail' in the undercut groove is also helpful in its detection. Measurement of undercut can be accurately determined using an undercut gauge shown in the following figure. Internal undercut on groove welds where access to the root is not possible requires UT or RT methods.

Set bottom of gage on base material. Set point on bottom of undercut. Read depth on scale at pointer. Locking screw can be tightened to hold reading for future reference.

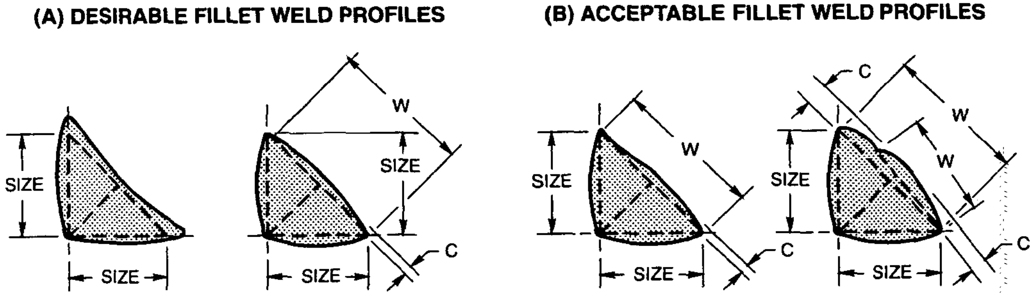



Repairs to undercut usually require light grinding and additional welding to replace the base metal removed during the undercutting and repair grinding.

| Common Causes and Remedies of Undercut | |
|---|---|
| **Causes** | **Remedies** |
| Excessive welding current | Reduce welding current |
| Excessive travel speed | Reduce travel speed |
| [illegible]on | Additional welder trair[illegible] |

# Weld Profiles

Visual inspection is very useful in determining the adequacy of weld profiles; the actual welds are compared with code or specification requirements regarding convexity or concavity for fillet welds, and face and root reinforcement for groove welds. The following profiles are found in AWS D1.1, *Structural Welding Code*. Additionally, fillet weld sizes can be determined using fillet weld gages; their use is shown on page 25.

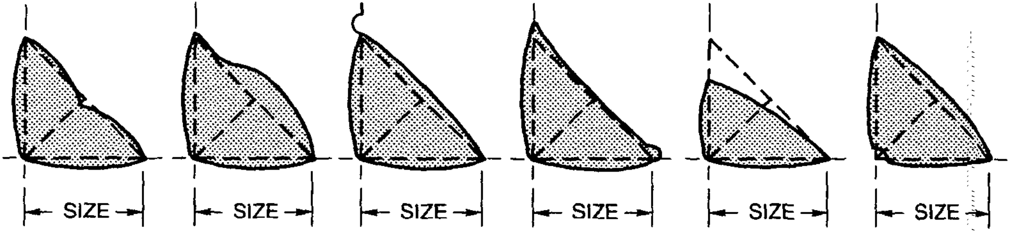



NOTE: CONVEXITY, C, OF A WELD OR INDIVIDUAL SURFACE BEAD WITH DIMENSION W SHALL NOT EXCEED THE VALUE OF THE FOLLOWING TABLE:

## MAXIMUM CONVEXITY OF FILLET WELDS

| WIDTH OF WELD FACE OR INDIVIDUAL SURFACE BEAD, W | MAX CONVEXITY, C |
|---|---|
| W ≤ 5/16 in. (8 mm) | 1/16 in. (1.6 mm) |
| W > 5/16 in. TO W < 1 in. (25 mm) | 1/8 in. (3 mm) |
| W ≥ 1 in. | 3/16 in. (5 mm) |

## (C) UNACCEPTABLE FILLET WELD PROFILES




INSUFFICIENT

EXCESSIVE CONVEXITY

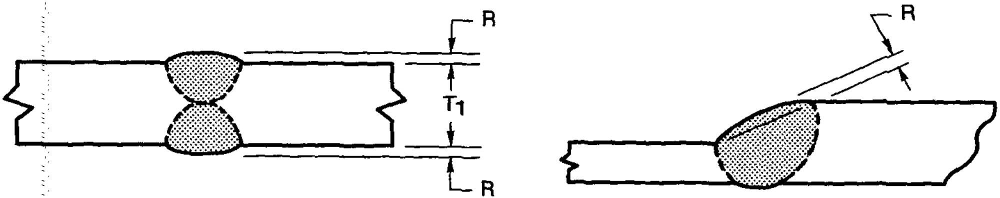
EXCESSIVE UNDERCUT

OVERLAP

INSUFFICIENT LEG

INCOMPLETE FUSION

## (D) ACCEPTABLE GROOVE WELD PROFILE IN BUTT JOINT

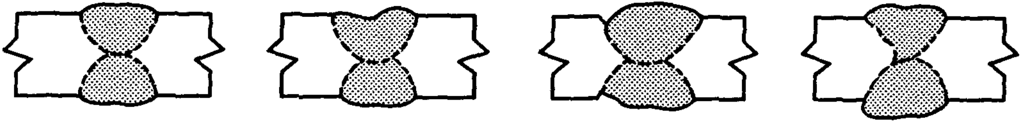



BUTT JOINT—
EQUAL THICKNESS PLATE

BUTT JOINT (TRANSITION)—
UNEQUAL THICKNESS PLATE

NOTE: REINFORCEMENT R SHALL NOT EXCEED 1/8 in. (3 mm).

## (E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS



EXCESSIVE REINFORCEMENT

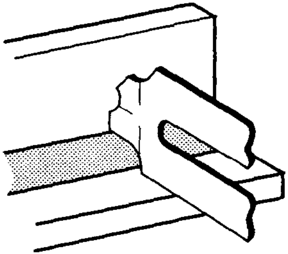
INSUFFICIENT THROAT

EXCESSIVE UNDERCUT

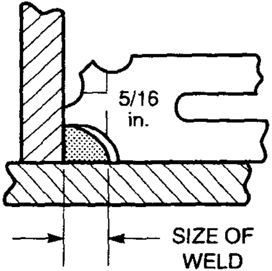
OVERLAP

# Fillet Weld Measurement

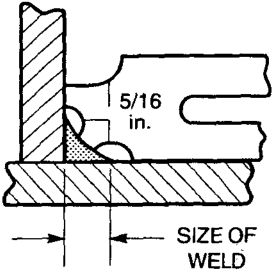
## How to Use Weld Fillet Gage



PLACEMENT




CONVEX WELDS




CONCAVE WELDS

BE CERTAIN BLADE EDGE IS SQUARE PARTS.

FOR CONVEX WELDS: USE BLADE WITH SINGLE ARC AT APPROPRIATE SIZE. FOR CONCAVE WELDS: USE BLADE WITH DOUBLE ARC AT APPROPRIATE SIZE.

# Dimensional Considerations

An important aspect of VT is the measurements for size, geometry, and assembly of welded structures. The manufacturing drawings will show the required lengths, widths, thicknesses, diameters, etc., of the various components, as well as weld sizes. The inspector should determine the dimensional tolerances for each of the measurements specified, and consider them during component measurement for conformance. If the tolerances are not stated, the inspector should ask for clarification. Often, these tolerances are noted as 'minimums,' 'maximums,' or a dimensional range such as "1.500 – 1.750 inches." The inspector should also be aware that measurements can be given in the U.S. Customary units, or in the S.I. or metric units.

## Dimensional Defects

### Incorrect Joint Preparation

1. Incorrect joint penetration subject to visual inspection, generally before welding is started, includes out-of-tolerance welding bevel or groove dimensions, base metal misalignment, and undesirable weld joint fit up conditions.
2. Included in the requirements for weld joint preparation shall be inspection for removal of scale, paint, oil, etc., from the weld joint.
3. Partial penetration weld joint preparations shall be visually inspected prior to welding to assure proper weld throat dimensions.

### Incorrect Weld Size

1. Incorrect weld size subject to visual inspection includes undersized fillet weld leg dimensions and underfilled groove weld throat dimensions.
2. Fillet weld size shall be determined by means of a fillet weld gage.

### Incorrect Final Dimensions

Incorrect final dimensions subject to visual inspection include all conditions of dimensional inaccuracies, distortion, and lack of conformity to design requirements.

# Thickness and Weight of Steel Plates: 1/32–1 inch

| Gage | Fraction | Decimal | mm | lb/ft² |
|---|---|---|---|---|
| 22 | 1/32 | 0.031 | 0.794 | 1.275 |
| 16 | 1/16 | 0.063 | 1.588 | 2.550 |
| 13 | 3/32 | 0.094 | 2.381 | 3.825 |
| 11 | 1/8 | 0.125 | 3.175 | 5.100 |
| 9 | 5/32 | 0.156 | 3.969 | 6.375 |
| 7 | 3/16 | 0.188 | 4.763 | 7.650 |
| 5 | 7/32 | 0.219 | 5.556 | 8.925 |
| 3 | 1/4 | 0.250 | 6.350 | 10.200 |
| 1 | 9/32 | 0.281 | 7.144 | 11.475 |
| Not Applicable | 5/16 | 0.313 | 7.937 | 12.750 |
| | 11/32 | 0.344 | 8.731 | 14.025 |
| | 3/8 | 0.375 | 9.525 | 15.300 |
| | 13/32 | 0.406 | 10.319 | 16.575 |
| | 7/16 | 0.438 | 11.112 | 17.850 |
| | 15/32 | 0.469 | 11.906 | 19.125 |
| | | 0.500 | 12.700 | 20.400 |

| Gage | Fraction | Decimal | mm | lb/ft² |
|---|---|---|---|---|
| Not Applicable | 17/32 | 0.531 | 13.494 | 21.675 |
| | 9/16 | 0.563 | 14.287 | 22.950 |
| | 19/32 | 0.594 | 15.081 | 24.225 |
| | 5/8 | 0.625 | 15.875 | 25.500 |
| | 21/32 | 0.656 | 16.669 | 26.775 |
| | 11/16 | 0.688 | 17.463 | 28.050 |
| | 23/32 | 0.719 | 18.256 | 29.325 |
| | 3/4 | 0.750 | 19.050 | 30.600 |
| | 25/32 | 0.781 | 19.844 | 31.875 |
| | 13/16 | 0.813 | 20.638 | 33.150 |
| | 27/32 | 0.844 | 21.431 | 34.425 |
| | 7/8 | 0.875 | 22.225 | 35.700 |
| | 29/32 | 0.906 | 23.019 | 36.975 |
| | 15/16 | 0.938 | 23.813 | 38.250 |
| | 31/32 | 0.969 | 24.606 | 39.525 |
| | 1 | 1.000 | 25.400 | 40.800 |

# Thickness and Weight of Steel Plates: 1–2 inch

| Fraction | Decimal | mm | lb/ft$^2$ |
|---|---|---|---|
| 1-1/32 | 1.031 | 26.194 | 42.075 |
| 1-1/16 | 1.063 | 26.988 | 43.350 |
| 1-3/32 | 1.094 | 27.781 | 44.625 |
| 1-1/8 | 1.125 | 28.575 | 45.900 |
| 1-5/32 | 1.156 | 29.369 | 47.175 |
| 1-3/16 | 1.188 | 30.163 | 48.450 |
| 1-7/32 | 1.219 | 30.956 | 49.725 |
| 1-1/4 | 1.250 | 31.750 | 51.000 |
| 1-9/32 | 1.281 | 32.544 | 52.275 |
| 1-5/16 | 1.313 | 33.338 | 53.550 |
| 1-11/32 | 1.344 | 34.131 | 54.825 |
| 1-3/8 | 1.375 | 34.925 | 56.100 |
| 1-13/32 | 1.406 | 35.719 | 57.375 |
| 1-7/16 | 1.438 | 36.513 | 58.650 |
| 1-15/32 | 1.469 | 37.306 | 59.925 |
| 1-1/2 | 1.500 | 38.100 | 61.200 |

| Fraction | Decimal | mm | lb/ft$^2$ |
|---|---|---|---|
| 1-17/32 | 1.531 | 38.894 | 62.475 |
| 1-9/16 | 1.563 | 39.688 | 63.750 |
| 1-19/32 | 1.594 | 40.481 | 65.025 |
| 1-5/8 | 1.625 | 41.275 | 66.300 |
| 1-21/32 | 1.656 | 42.069 | 67.575 |
| 1-11/16 | 1.688 | 42.863 | 68.850 |
| 1-23/32 | 1.719 | 43.656 | 70.125 |
| 1-3/4 | 1.750 | 44.450 | 71.400 |
| 1-25/32 | 1.781 | 45.244 | 72.675 |
| 1-13/16 | 1.813 | 46.038 | 73.950 |
| 1-27/32 | 1.844 | 46.831 | 75.225 |
| 1-7/8 | 1.875 | 47.625 | 76.500 |
| 1-29/32 | 1.906 | 48.419 | 77.775 |
| 1-15/16 | 1.938 | 49.213 | 79.050 |
| 1-31/32 | 1.969 | 50.006 | 80.325 |
| 2 | 2.000 | 50.800 | 81.600 |

## Commercial Pipe Sizes and Wall Thicknesses (ASA-B36.10 and B36.19)

| Nominal Pipe Size | Outside Diam. | Nominal Wall Thicknesses in inches for | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sched. 5s[1] | Sched. 10s[1] | Stan-dard[2] | Sched. 40 | XS[3] | Sched. 80 | Sched. 120 | Sched. 160 | XX Strong |
| 1/8 | 0.405 | — | 0.049 | *0.068* | 0.068 | *0.095* | 0.095 | — | — | — |
| 1/4 | 0.540 | — | 0.065 | *0.088* | 0.088 | *0.119* | 0.119 | — | — | — |
| 3/8 | 0.675 | — | 0.065 | *0.091* | 0.091 | *0.126* | 0.126 | — | — | — |
| 1/2 | 0.840 | 0.065 | 0.083 | *0.109* | 0.109 | *0.147* | 0.147 | — | 0.188 | 0.294 |
| 3/4 | 1.050 | 0.065 | 0.083 | *0.113* | 0.113 | *0.154* | 0.154 | — | 0.219 | 0.306 |
| 1 | 1.315 | 0.065 | 0.109 | *0.133* | 0.133 | *0.179* | 0.179 | — | 0.250 | 0.358 |
| 1-1/4 | 1.660 | 0.065 | 0.109 | *0.140* | 0.140 | *0.191* | 0.191 | — | 0.250 | 0.382 |
| 1-1/2 | 1.900 | 0.065 | 0.109 | *0.145* | 0.145 | *0.200* | 0.200 | — | 0.281 | 0.400 |
| 2 | 2.375 | 0.065 | 0.109 | *0.154* | 0.154 | *0.218* | 0.218 | — | 0.344 | 0.436 |
| 2-1/2 | 2.875 | 0.083 | 0.120 | *0.203* | 0.203 | *0.276* | 0.276 | — | 0.375 | 0.552 |
| 3 | 3.5 | 0.083 | 0.120 | *0.216* | 0.216 | *0.300* | 0.300 | — | 0.438 | 0.600 |
| 3-1/2 | 4.0 | 0.083 | 0.120 | *0.226* | 0.226 | *0.318* | 0.318 | — | — | — |
| 4 | 4.5 | 0.083 | 0.120 | *0.237* | 0.237 | *0.337* | 0.337 | 0.438 | 0.531 | 0.674 |
| 5 | 5.563 | 0.109 | 0.134 | *0.258* | 0.258 | *0.375* | 0.375 | 0.500 | 0.625 | 0.750 |
| 6 | 6.625 | 0.109 | 0.134 | *0.280* | 0.280 | *0.432* | 0.432 | 0.562 | 0.719 | 0.864 |

**NOTES:**

1. Schedules 5s and 10s are available in corrosion resistant materials and Schedule 10s is also available in carbon steel in sizes 12 in. and smaller.
2. Thicknesses shown in *italics* are also available in stainless steel, under the designation Schedule 40s.
3. [illegible] re also available in stainless steel, under [illegible]

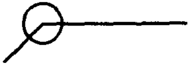
## Metric Conversion Table
(Commonly used conversions)

| Property | To Convert From | To | Multiply by |
|---|---|---|---|
| area | inches$^2$ | millimeters$^2$ | $6.452 \times 10^2$ |
| | millimeters$^2$ | inches$^2$ | $1.550 \times 10^{-3}$ |
| flow rate | feet$^3$/hour | liters/minute | 0.472 |
| | liters/minute | feet$^3$/hour | 2.119 |
| linear | inches | millimeters | 25.4 |
| | millimeters | inches | $3.937 \times 10^{-2}$ |
| | inches | centimeters | 2.54 |
| | centimeters | inches | 0.3937 |
| | feet | meters | 0.305 |
| | meters | feet | 3.281 |
| mass (weight) | pounds | kilograms | 0.454 |
| | kilograms | pounds | 2.205 |
| pressure | psi | kilopascal (kPa) | 6.895 |
| | kPa | psi | 0.145 |
| tensile strength | psi | megapascal (MPa) | $6.895 \times 10^{-3}$ |
| | MPa | psi | $1.450 \times 10^2$ |

# Nondestructive Testing Symbols

The examination symbol consists of the following elements:

1. Reference line
2. Arrow
3. Examination method letter designations
4. Extent and number of examinations
5. Supplementary symbols
6. Tail (Specifications, codes, or other references)

| Examine All Around | Field Examination | Radiation Direction |
|---|---|---|
|  |  |  |

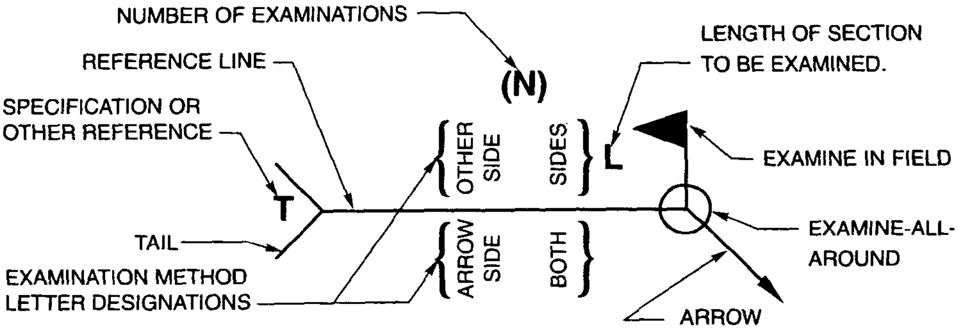
## Examination Method Letter Designations

Nondestructive examination methods shall be specified by use of the letter designation shown below.

| Examination Method | Letter Designation |
|---|---|
| Acoustic emission | AET |
| Electromagnetic | ET |
| Leak | LT |
| Magnetic particle | MT |
| *Neutron radiographic* | *NRT* |
| Penetrant | PT |
| Proof | PRT |
| Radiographic | RT |
| Ultrasonic | UT |
| Visual | VT |

## Standard Location of Elements of a Nondestructive Examination Symbol

The elements of a nondestructive examination symbol shall have standard locations with respect to each other as shown in the following figure.




**Standard Location of Elements**

## Other Publications Available from AWS

| Order No. | Title |
|---|---|
| B1.11 | Guide for the Visual Examination of Welds<br>*Excellent tutorial; most illustrations in color. 32 pages, softbound.* |
| WI | Welding Inspection<br>*Perennial best seller; 222 pages, softbound.* |
| B1.10 | Guide for the Nondestructive Examination of Welds<br>*DoD adopted; concise reference tool, 41 pages, softbound.* |
| CM | Certification Manual for Welding Inspectors<br>*Aid to studying for CWI exam as well as excellent introduction to weld inspection; 300 pages, softbound.* |
| D18.2 | Guide to Weld Discoloration Levels on Inside of Austenitic Stainless Steel Tube<br>*Laminated guide shows results of increasing amounts of oxygen in shielding gas.* |
| A2.4 | Standard Symbols for Welding, Brazing, and Nondestructive Examination<br>*Used by Departments of Transportation and Defense; ANSI approved, 100 pages, softbound.* |

--der these or other AWS publications, call (800) 334-9353 or visit www.aws.org.

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