



Oklahoma DOT Materials & Testing

January 14, 2004

(Updated to reference current URLs 02/17/2023)

Publication: GFA-FW

FIELD ACCEPTANCE OF FIELD WELDING GUIDE

This guide is made available for use in conjunction with the Code, specifications and contract requirements. It is important to note that, whenever members which require field welding are pre-fabricated in a shop, standard shop drawing detailing practices should result in the Shop Fabricator including in their shop drawings:

- Erection details and/or drawings
- Field Notes
- Field Weld Symbols

In every such case, the relevant approved shop drawings play an essential role in proper field fit-up, field welding and field acceptance issues. However, shop inspection does not, by default, include field work.

Contact the **Structural Materials Branch of the ODOT Materials Division**

(<https://oklahoma.gov/odot/about/contact-us/materials.html>) for assistance in interpretation of any drawing or specification, whenever any special field non-destructive testing is indicated (such as UT) and to direct any question concerning field welding issues.

Reference Documents:

- ANSI/AASHTO/AWS D1.5 Bridge Welding Code
- Oklahoma DOT Standard Specification 724.03 - Welding
- Oklahoma DOT Special Provision 724-3(a) 99 - Special Provision for Welding
- Oklahoma DOT Publication: Qualification Testing of Field Welders
- Oklahoma DOT Approved List: SiteManager Welders List

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QUALIFICATION OF FIELD WELDERS

Field Welders are required to have and use proper equipment and be qualified as described in the following ODOT Materials Division publication:

Qualification Testing of Field Welders (<https://www.odot.org/materials/pdfs/FWELDR.pdf>)

Field Welders having successfully passed the qualification test are entered into the Department's construction management database and publicly displayed on:

Field Welders List (<https://www.odot.org/materials/htm-smap/110612.html>)

All listed Field Welders were issued a "Welder Operator Certification" card. On the reverse side of the card is a space for a Resident Engineer or designated representative to document satisfactory field weld information relative to Oklahoma DOT specification projects.

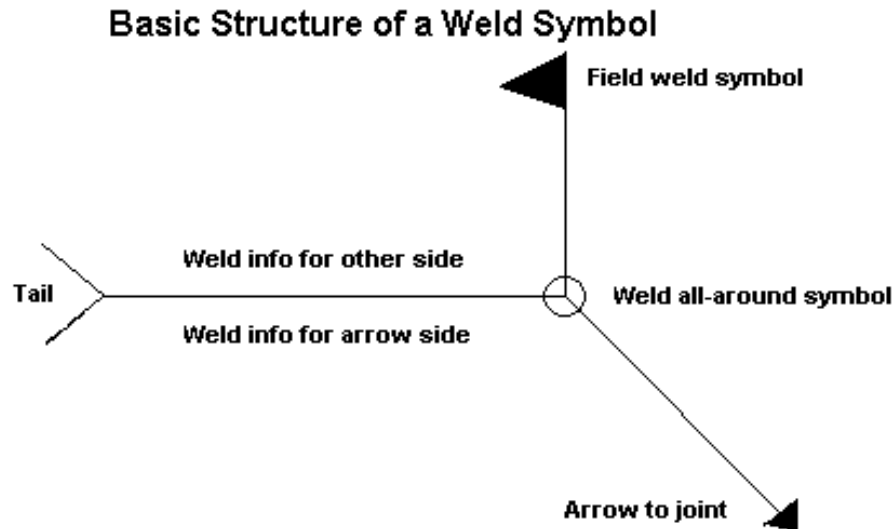
Cards are to be considered void following any 12 month period after issuance in which the welder has not accomplished such welding.

To determine if a Field Welder is qualified:

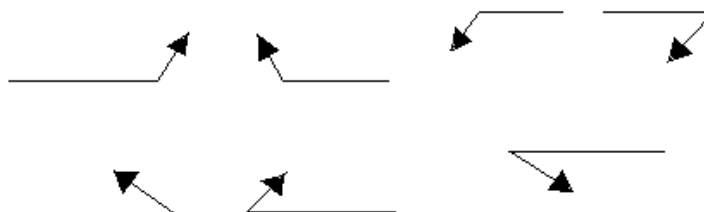
- Check the List
- Check the reverse side of their card

WELD SYMBOLS

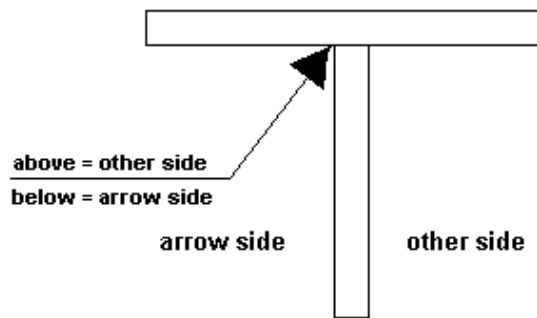
When field welds are specified on construction and fabrication drawings, a cryptic set of symbols is used as a sort of shorthand for describing the type of weld, its size, and other processing and finishing information. The purpose of this section is to introduce the most common symbols and their meaning.



The horizontal or reference line is the anchor to which all other welding symbols are tied. The instructions for making the weld are strung along the reference line. An arrow connects the reference line to the joint that is to be welded. In the example above, the arrow is shown growing out of the right end of the reference line and heading down and to the right, but many other combinations are allowed.



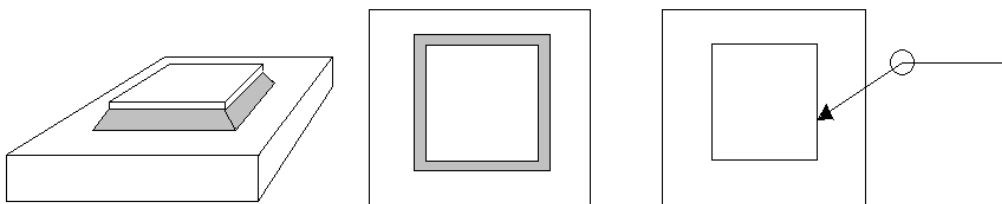
Quite often, there are two sides to the joint to which the arrow points, and therefore two potential places for a weld. For example, when two steel plates are joined together in a T shape, welding may be done on either side of the stem of the T.

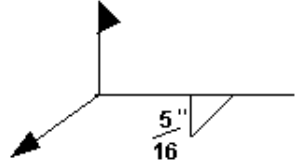
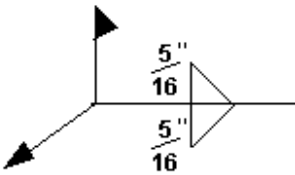
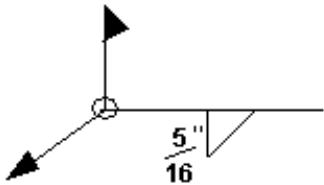
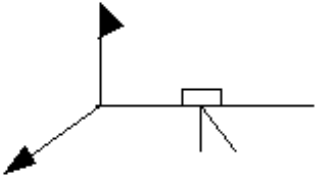


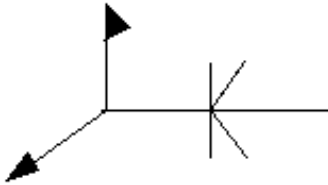
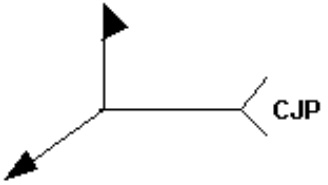
The weld symbol distinguishes between the two sides of a joint by using the arrow and the spaces above and below the reference line. The **below = arrow side** and **above = other side** rules apply regardless of the arrow's direction.

A **flag** growing out of the arrow/reference line junction is present if the weld is to be made in the field during erection of the structure. A weld symbol without a flag indicates that the weld is to be made in the shop. Information may be included in the **tail** regarding the weld process.

An open circle at the arrow/reference line junction is present if the weld is to go all around the joint, as in the example below:



Some Common Field Welds	Their Symbols
<p>5/16" Fillet Weld, Arrow Side</p>	
<p>5/16" Fillet Weld, Arrow Side and Other Side (Both Sides)</p>	
<p>5/16" Fillet Weld-All-Around</p>	
<p>Single-Bevel-Groove Weld with Backing</p> <p>Details at the open end of the groove symbol may include root opening (gap between members), groove angle and possible contour & finish information.</p> <p>An "R" within the backing box detail would indicate the backing is to be removed after welding.</p>	

<p>Double-Bevel-Groove Weld</p> <p>Details at the open ends of the groove symbols may include root opening (gap between members), groove angle and possible contour & finish information.</p>	
<p>Complete Joint Penetration</p> <p>Also sometimes detailed CP in the tail, either one indicates complete penetration of weld regardless of type of weld or joint preparation.</p>	

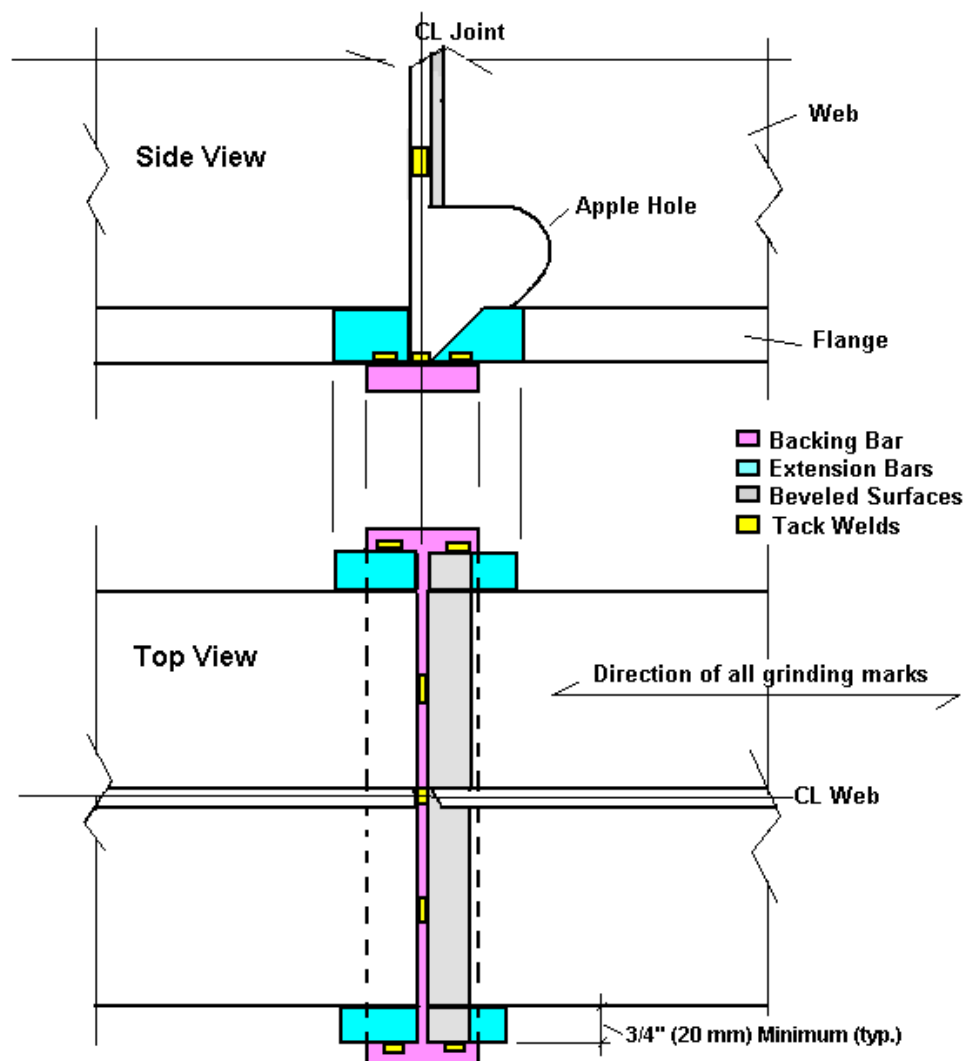
Weld symbols relay a great deal of information, but not everything that may be pertinent. The following picture is to provide a brief discussion on a bridge girder replacement section splice. These are perhaps the most critical types of welds Field Welders will be faced with.

Apple holes and bevels on the replacement section are typically prepared in the fabrication shop by the fabricator of the replacement section. Apple holes allow the welder access to the flange weld, should be very smooth and remain open after weld completion.

In the picture below, notice how:

- backing bar extends beyond the splice
- extension bars match the flange (both in thickness and bevel preparation) and extend it out
- tack welds are only made within the final weld area or on metal which will be removed
- all finished grinding marks should be in the direction of applied stress (lengthwise of girder)

Once welded, all backing and extension bars are required to be removed and surfaces ground flush. Some cleaning into sound weld metal and welding on the backing bar side may be necessary. If the backing bar is removed first, the extension bars are beneficial for that weld as well. This type of weld requires complete joint penetration and typically requires UT or some other nondestructive testing.



CLEANING

One of the first steps in making any sound field weld, regardless of type, will be to properly pre-clean the joint. One of the most desirable tools is a stiff wire brush.



All surfaces to be welded must be free from all paint, loose or thick scale, slag, rust, moisture, grease or other foreign material by Code. Mill scale that can withstand a vigorous wire brushing may remain. All finished welds are to be cleaned as well.

Multiple pass welds should be cleaned between every pass. This is typically accomplished by using a stiff wire brush in conjunction with a chipping hammer. The chipping hammer removes slag and splatter. The grinder is also a very common and useful tool for cleaning. Grinders are to be used with care to avoid doing more harm than good to both finished welds and the base metal.



Slag is a byproduct of welding. It typically adheres to the weld surface. Slag must be removed between passes and upon weld completion. A finished weld should have a clean appearance.

PRE-WELD & INTERPASS HEATING

Heating is an important part of welding. Preheating the joint helps remove any moisture. It also allows the joint to cool at a slower rate which will allow additional time for hydrogen to diffuse out of the molten weld metal. Preheating is the required practice of providing localized heat to the weld zone. The most common method is by use of a manual torch.



Required preheat is to be applied for a distance of 3" in all directions from the weld joint. Minimum preheat and interpass temperatures are to be in accordance with Table 4.4 of ANSI/AASHTO/AWS D1.5. The most applicable are also included below:

Thickness of Thickest Part at Point of Welding in inches (millimeters)				
Welding Process & Base Metal	To 3/4" (20 mm)	Over 3/4" (20 mm) to 1 1/2" (40 mm) Incl.	Over 1 1/2" (40 mm) to 2 1/2" (60 mm) Incl.	Over 2 1/2" (60 mm)
SMAW A36, A572 (A709 - Gr. 36, 50, 50W)	50 deg. F (10 deg. C)	70 deg. F (20 deg. C)	150 deg. F (65 deg. C)	225 deg. F (110 deg. C)

In accordance with Standard Specification 724.03(a), No welding is to be allowed when the ambient air temperature around the weld joint is lower than 20 deg. F (-6 deg. C), when surfaces are wet or exposed to rain, snow, harmful wind or when operators are exposed to inclement conditions that will hamper good workmanship.

The most common method for checking preheat is by using a temperature crayon. Using temperature crayons becomes more essential when welding thicker members.



Typically, temperature crayons will be labeled for a specific temperature. If the weld joint has reached the label temperature, the temperature crayon will melt when rubbed across the base metal.

ELECTRODES

Shielded Metal Arc Welding (SMAW) is the only process for which Field Welders are pre-qualified by Materials Division's process. The following picture shows what SMAW electrodes look like:



Electrodes should be identifiable by markings printed on them. All electrodes must be of the low-hydrogen classification. The most commonly used electrode will be E7018. However, E8018 C3 would be appropriate when the weld and welded member will remain unpainted. Field Welders used E7018 electrodes when taking their weld qualification test. E6011 electrodes are not appropriate.

E 70 1 8

The first 2 numbers stand for the minimum tensile strength of the electrode. 70 indicates a tensile strength of 70 ksi, 80 indicates 80 ksi.

The third number indicates the weld position(s) for which the electrode may be used.

- 1 means the electrode may be used in all weld positions
- 2 would mean the electrode may be used in the flat and horizontal weld positions

The fourth number indicates the type of coating

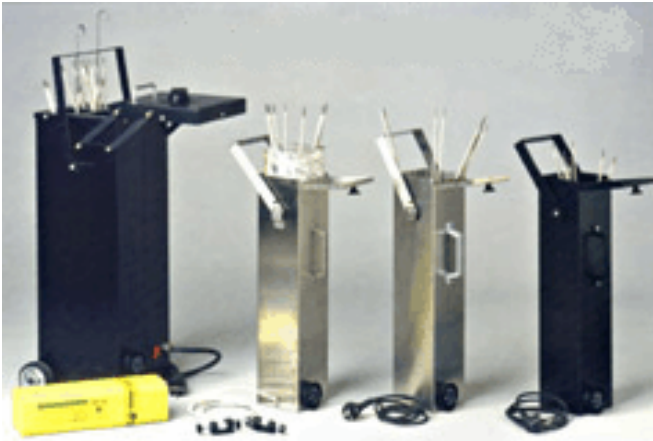
- 6 or 8 means the electrode is classified as low-hydrogen

Hydrogen is one of the major causes for weld defects. Care must be taken to ensure no moisture is picked up in the coating on the electrodes.

Electrodes are to be purchased in hermetically sealed containers or shall be dried for at least 1 hour between 700 and 800 deg. F (370 and 425 deg. C).

Immediately after opening hermetically sealed containers, electrodes not being used must be stored in a portable oven (also known as a hot box) and held at a temperature of at least 250 deg. F (120 deg. C)

Examples of portable ovens (hot boxes):



After electrodes are removed from hermetically sealed containers or from the portable oven, they may be exposed to the atmosphere for periods not to exceed:

- E70XX 4 hours maximum
- E80XX 2 hours maximum

If the electrodes have been exposed to the atmosphere for a period less than shown above, they may be placed back into the portable oven and dried for a period of no less than 4 hours.

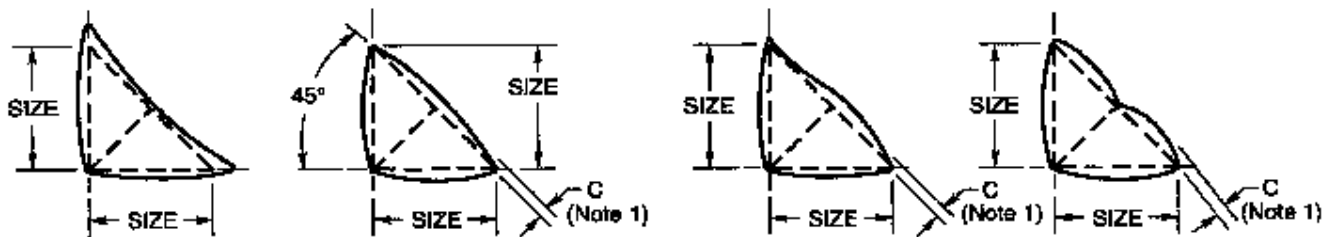
In any case, electrodes that have been wet shall not be used.

FILLET WELD PROFILES

The most common welds that will need to be checked in the field are fillet welds. Fillet welds are designed based on their leg sizes. If the drawings show a fillet weld of 5/16" then each leg of the weld needs to measure to that dimension. If either leg is under the specified dimension, the strength of the weld will be less than required by design. The throat of the weld should be checked also. AASHTO/AWS D1.5 Bridge Welding Code shows acceptable and unacceptable weld profiles. These are shown below:

AASHTO/AWS D1.5MD1.5:2002

WORKMANSHIP

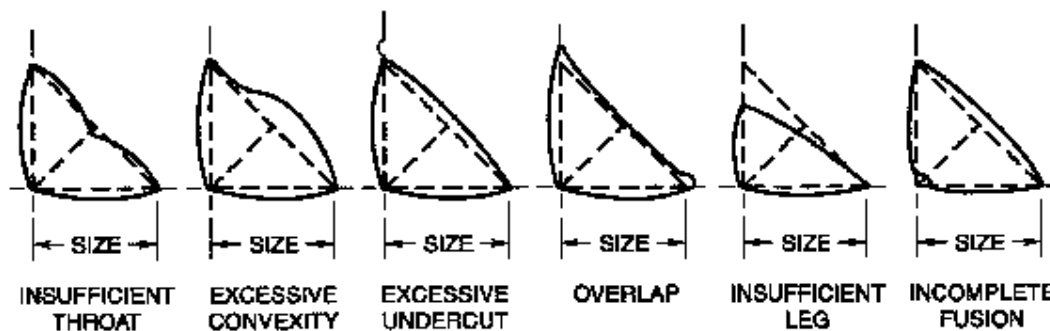


(A) DESIRABLE FILLET WELD PROFILES

(B) ACCEPTABLE FILLET WELD PROFILES

Note:

1. Convexity, C, of a weld or individual surface bead shall not exceed 0.07 times the actual face width of the weld or individual bead, respectively, plus 1.5 mm [0.06 in.].



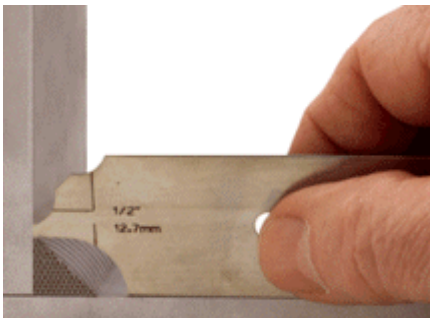
(C) UNACCEPTABLE FILLET WELD PROFILES

Although leg sizes can be checked by a measuring tape, the best way to check fillet weld size is by using a fillet weld gauge. There are different types of gauges. Field Welders are responsible to have their own gauges and use them. Following is a brief discussion on a common type of fillet weld gauge and how to use it.

The most common fillet weld gauges come in a set, for various size fillet welds.



Select appropriate size blade. For convex welds, use blade with single arc.



For concave welds, use blade with double arc to check for sufficient throat.



SPOTTING COMMON DEFECTS

Defects require repair. To assure any repair does more good than harm, it should be carefully planned and have a defined procedure. If you spot a defect and are unsure about repair, contact the Structural Branch of the ODOT Materials Division.

Some of the most common weld defects are profile problems of fillet welds as identified in Fillet Weld Profiles section. All welds should be visually inspected for other defects as well. Common defects to look for include the following:

Cracks

No cracks in the surface of the welds shall be allowed. If a crack is found, it must be completely removed and more extensive testing performed (such as magnetic particle inspection) to ensure all of the crack has been removed.

Porosity

Porosity is a cavity in the weld that is formed by gas escaping from the molten weld metal during solidification. The ANSI/AASHTO/AWS D1.5 limitation for porosity is:

- Maximum diameter shall not exceed 3/32" (2.4 mm)
- Frequency of any sized porosity shall not exceed one in 12" (300 mm) or six in 4 feet (1200 mm) of weld length

Craters

Craters are the ends of welds where the weld is not filled to its full cross section. Stresses caused by craters may result in cracks forming. All welds are to have full cross section for their entire length.

Undercut

Undercut refers more to the base metal adjacent to the weld, and is usually caused by excessive current in the weld operation. Undercut is a reduction of base metal area, causes stress risers and should be avoided. ANSI/AASHTO/AWS D1.5 limitation for undercut is:

- No more than .01" (.25 mm) deep when weld is transverse to tensile stress
- No more than 1/32" (1 mm) deep for all other cases

Wayward Arc Strikes

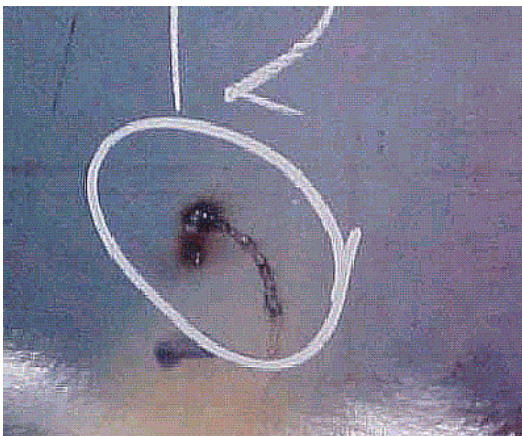
Wayward arc strikes are outside of the final weld area. They occur when either the electrode or a damaged lead line (worn insulation) comes in contact with base metal away from the weld. Arcs are to be struck well within the final weld area only.

Wayward arc strikes cause very rapid heating and cooling, may result in hardening, fatigue cracking or fractures.

All arc strikes are to be removed by grinding, but care must be taken to not make the problem worse. Grinding to a depth of 1/8" below the original surface should remove all traces of the wayward arc strike and its heat affected zone. Grinding, alone, results in significant and possible inappropriate area reduction.

In tension areas of bridge members where wayward arc strikes occur, the Code requires additional and more extensive testing (such as magnetic particle inspection and hardness testing).

Example of a wayward arc strike:



EXAMPLES OF GOOD AND BAD BEADS

TOP VIEWS

CROSS SECTIONS

GOOD

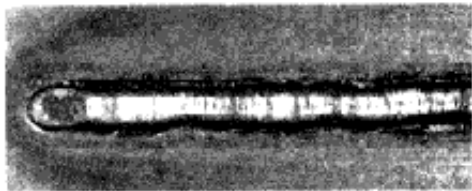
Proper
Current
Voltage &
Speed



A smooth, regular
bead. No undercutting
or piling up. Uniform in
cross section.

BAD

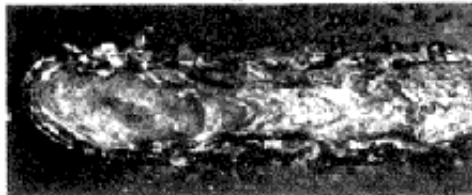
Welding
Current
too Low



Excessive piling up of
weld metal.
Overlapping bead has
poor penetration.

BAD

Welding
Current
too High



Excessive spatter to
be cleaned off.
Undercutting along
edges weakens joint.
Irregular deposit.

BAD

Arc too Long
(Voltage too
High)



Very irregular bead
with poor penetration.

BAD

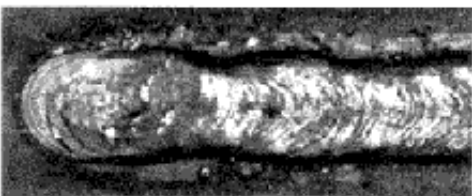
Welding
Speed
Too Fast



Bead too small, with
irregular contour. Not
enough weld metal in
cross section. Weld
not strong enough

BAD

Welding
Speed
Too Slow



Excessive piling up of
weld metal.
Overlapping without
penetration at edges.