

Weld Faults and Causes

PART OF THE CWB CERTIFICATE PROGRAMS



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WELD FAULTS AND CAUSES

LESSON OBJECTIVES

Upon completion of this module, the student will have sufficient knowledge to enable him to identify weld faults and their general causes.

The intent of this module is to provide a basic background, and not an intense study of the subject such as may be found in Quality Control Courses which are generally available.

This module will include discussions on the following subjects:

- General Classes of Weld Faults
- Dimensional Faults & Typical Causes
- Structural Discontinuities & Typical Causes
- Anomalies (Weld Metal and Physical)
- Procedure Standards

WELD FAULTS CLASSIFICATION

Faults in welding may range from faulty metallurgical characteristics to such physical imperfections as cracks, porosity, slag inclusions, lack of fusion, undercut, lack of penetration, dimensional defects etc. The importance of weld defects, however, both as to type and quantity, is relative to the type of weldment and the service required; an imperfection harmful in one case need not be so where other types of welded work are concerned. It is, therefore, a difficult task to assess their relative importance, since the extent and type of a weld fault needs to be analyzed in relation to the function of a given weldment. Where experience is inadequate, this should be done by experimental research including the necessary tests to establish standards of acceptability.

There are certain types of defects which may occur in arc welding and they are of three general classes—

1. Dimensional Defects
2. Structural Discontinuities in the Weld
3. Defective Properties (Weld Metal and Joint)

These classes of defects can be subdivided under many headings, but since it is impossible to state rules whereby an inspector can identify all the factors likely to cause defects in the welds, this module will describe only some of them briefly. An inspector will be better fitted to judge the chances of obtaining welds which are satisfactory for a particular service if he has a thorough knowledge of the limitations of a given welding process and an understanding of those conditions which are likely to cause the formation of defects.

Dimensional Faults

The production of satisfactory weldments depends upon, among other things, the maintenance of specified dimensions, whether it be size and shape of welds or the finished dimensions of an assembly. Requirements of this nature will be found in the drawings and specifications. Departure from the requirements in any respect should be regarded as a dimensional defect which must be corrected before final acceptance of the weldment. The more common types of these defects are discussed as follows.

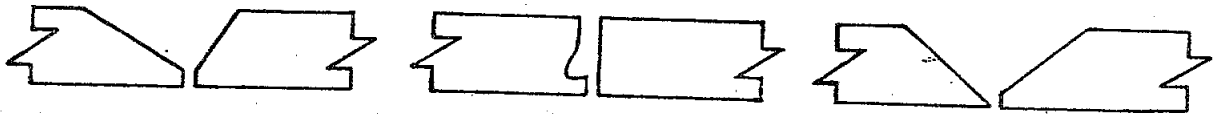
Dimensional Faults Prior to Welding

- a) Incorrect Bevel Angles
- b) Incorrect J Groove Radii
- c) Incorrect Root Face
- d) Incorrect Fit Up (Mismatch)
- e) Incorrect Root Openings
- f) Irregularities in the Surfaces of the Joint Preparation

Causes

Faults described under (a), (b), (c), (d), (e) and (f) are the direct result of poor workmanship in operations leading up to the point at which the assembly is to be welded.

Faults of this nature indicate a lack of quality control and should be reported by the welding inspector so that corrective action may be initiated. Fig. 1 illustrates some dimensional faults.



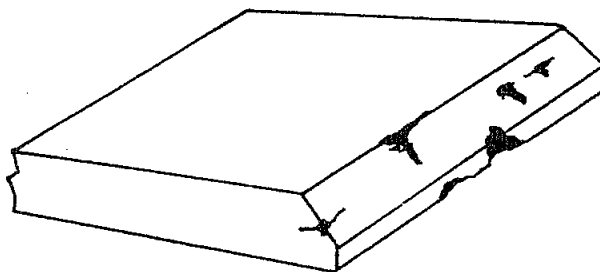
(a) – *Incorrect Bevel Angles* (b) – *Incorrect J-Groove Radii* (c) – *Incorrect Root Face*



(d) – *Incorrect Fit-Up*



(e) – *Incorrect Root Opening*



(f) – *Irregularities in Joint Preparation Surfaces*

Fig. 1

As illustrated in Fig. 2, codes and specifications provide for tolerances on Bevel Angle, Root Face Thickness and Root Openings, and should be followed accordingly.

CSA Standard W59 — 1977 and AWS D1.1 — 80

	Root Not Gouged	Root Gouged
1. Root Face of Joint	$\pm 1/16$ inch	Not limited
2. Root Opening of Joints:		
- Without Steel Backing	$\pm 1/16$ inch	+ $1/16$ inch - $1/8$ inch
- With Steel Backing	+ $1/4$ inch - $1/16$ inch	Not applicable
3. Groove Angle of Joint	+ 10 degrees - 5 degrees	+ 10 degrees - 5 degrees

Fig. 2

(not applicable to electroslag or electrogas welding)

e.g., A groove angle specified on the drawing as 60° should be between 55° and 70° .

Incorrect Joint Fit-Up also represents difficulties in producing sound weld deposits. Care should be taken to meet the fit-up tolerances to avoid the following weld faults:

Insufficient Root Openings

- Lack of Penetration
- Lack of Fusion
- Slag Entrapment

Excessive Root Openings

- Porosity
- Slag Entrapment
- Excessive Weld Reinforcement
- Additional Distortion

Incorrect Joint Preparation and Fit-Up

Good welding practice requires *proper joint dimensions and preparation*. Improper joint preparation makes it exceedingly difficult for the operator to make a sound weld and greatly increases the tendency to produce structural discontinuities in the weld. Therefore, it is important that the joint preparation meet the applicable welding standards *within specified limits*.

Incorrect joint preparation could be caused by one, or a combination of the following:

- Improper Bevel Angles or J-Groove Radius
- Improper Root Face
- Irregularities in the Finished Surface

Irregularities in the finished surface to be welded may also lead to various weld faults and defects. The method of preparation usually determines the type of weld fault that may be experienced as illustrated below.

Sheared Surfaces:—

Dependent on the condition of the shear blades and lubricants used, various undesirable foreign materials may be entrapped leading to porosity, slag entrapment and lack of fusion.

Flame Cut Surfaces:—

When oxygen is used in flame cutting, notches and irregularities may occur. Quite often, slag may adhere to these notches and surfaces, and if it is not removed prior to welding, such faults as porosity, lack of fusion, slag entrapment and chemistry composition defects may occur.

Codes, Standards and Specifications often limit surface irregularities and should be followed accordingly. For example, when welding in accordance to CSA Standard W59 specifications (as in Fig. 3), the following conditions and limitations are to be applied:

5.3 Preparation of Material

5.3.1 Surfaces and edges to be welded shall be smooth, uniform, and free from fins, tears, cracks and other defects which would adversely affect the quality or strength of the weld. Surfaces to be welded shall also be free, within 2 inches of any weld location, from loose or thick scale (except for tightly adhering small islands of scale), slag, rust, paint, grease, moisture and other foreign material that will prevent proper welding or produce objectionable fumes.

5.3.2 Occasional notches, not more than 3/16 inch deep, on otherwise satisfactory surfaces shall be removed by machining or grinding. Occasional notches, exceeding 3/16 inch and less than 7/16 inch deep, in oxygen cut edges of plate up to 4 inches thick, not to be welded, may, with the Engineer's approval be repaired by welding. For material 4 inches thick or over the depth of the notch shall not exceed 5/8 inch.

Such repairs shall be made by suitably preparing the defective area, welding with basic electrodes to an approved procedure and grinding the completed weld, smooth and flush with the adjacent surface to produce a workmanlike finish.

Fig. 3

(Extract from CSA Standard W59)

Dimensional Faults After Welding

- a) Distortion
- b) Incorrect Weld Profile Such As:
 - i) Convexity
 - ii) Concavity
 - iii) Insufficient throat
 - iv) Insufficient leg
 - v) Excessive reinforcement
 - vi) Undercutting (internal & external)
 - vii) Overlap
 - viii) Out of line weld beads.

DISTORTION OR WARPAGE

Causes

The welding operation involves the application of heat and the fusion of metal in localized sections in the weldment. Stresses of sufficient magnitude may be set up (due to thermal expansions and contractions) which will cause distortion of the structure.

Distortion may have a number of contributing causes such as.—

- a) Lack of control of heat input
- b) Inadequate control of weld pass sequencing
- c) Inaccurate preparation of the joint
- d) Inadequate control on fit-up
- e) Incorrect joint design.

Various codes and specifications provide *Dimensional Tolerances* as illustrated in Fig. 4. It should be noted that other codes, such as AWS D1.1, for example, have similar specifications.

CSA W59

5.6 Dimensional Tolerances

The dimension of welded structural members shall be within the tolerances of the general specifications governing the work and also within the following special tolerances:

Lengths of 45 feet and under:

$$1/8'' \times \frac{\text{Number of feet of total length}}{10} \quad \text{—but not over } 3/8''$$

Lengths over 45 feet:

$$3/8'' + 1/8'' \frac{\text{Number of feet of total length} - 45}{10}$$

Fig. 4

Incorrect Weld Profiles

Weld deficiencies related to weld profiles are illustrated in Figs. 5 and 6.

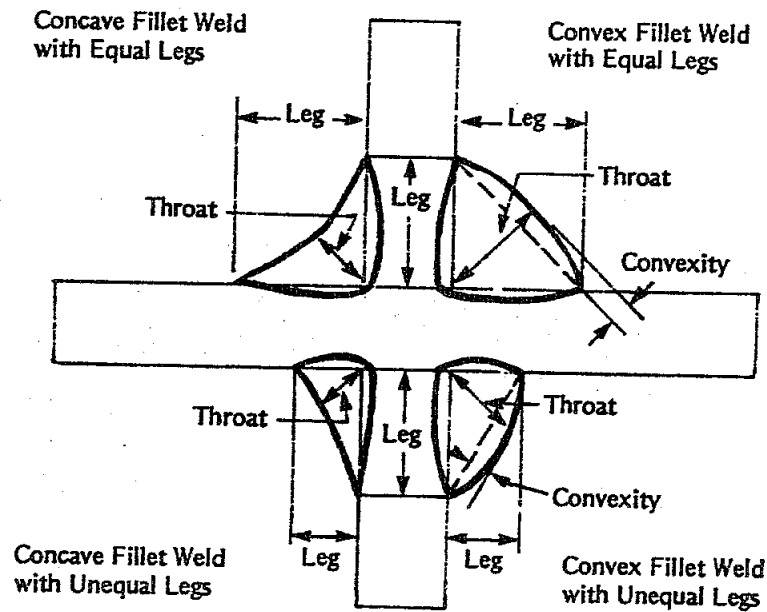


Fig. 5

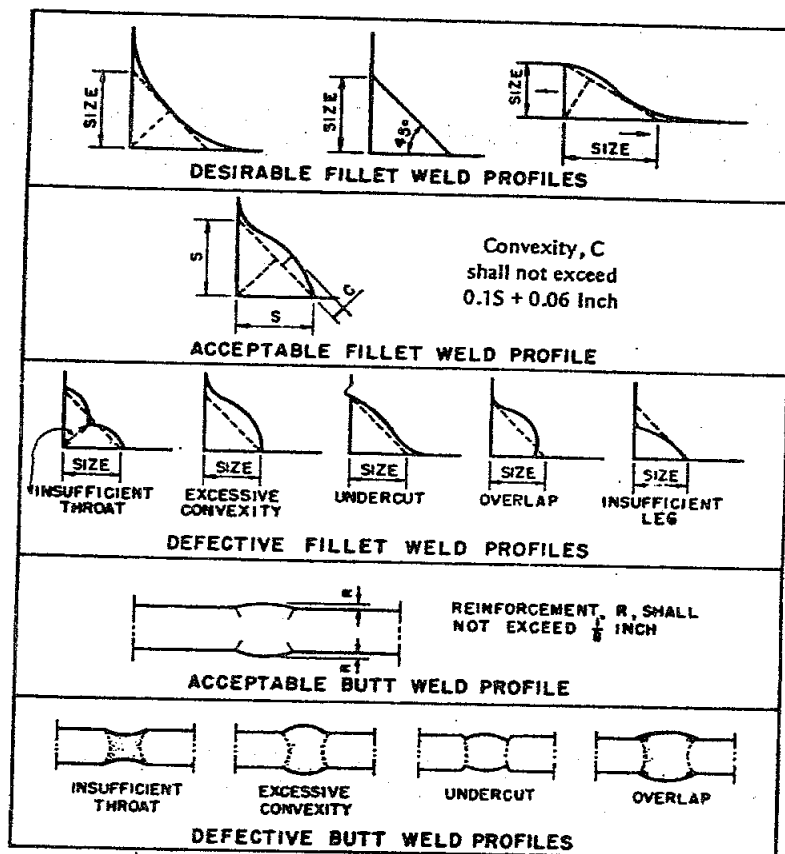


Fig. 6 - Weld Profiles

Acceptable and Defective with various faults illustrated in accordance with CSA Standard W59 (AWS D1.1-80 is similar).

Overlap is a condition where an excess of weld metal exists at the toe of a weld beyond the limits of fusion and is illustrated in Figs. 7 and 8. This condition produces notches which are harmful due to a resultant stress concentration under load, and, in the case of a fillet weld, may actually reduce its effective size.

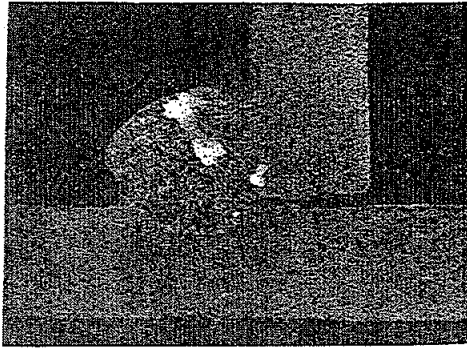


Fig. 7 — Overlap in Fillet

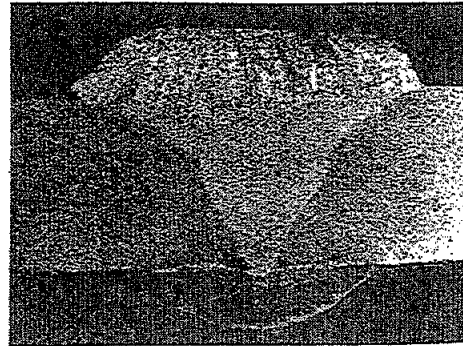


Fig. 8 — Overlap in a Groove Weld

If the nature of overlap is examined, it will be found that there is a mass of weld metal that is not fused to the parent metal. Overlap is common in Fillet and Groove welds with various processes, and typical causes of overlap are as follows:

- *Improper Techniques, including*

- Travel speed is too slow
- Improper electrode angles
- Improper weave techniques

- *Essential Variables, including*

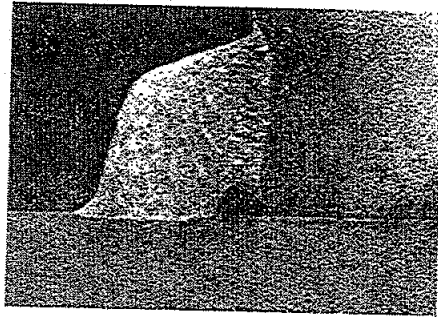
- Insufficient electrode diameter
- Improper amperage and voltage settings

- *Joint Preparation Contaminants, including*

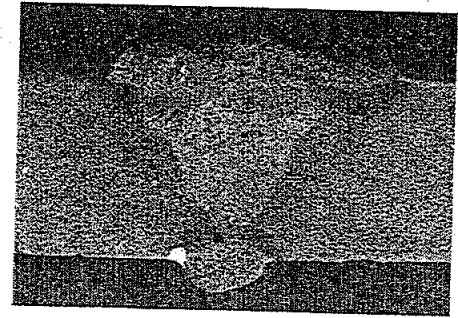
- Oil
- Paint
- Rust
- Mill Scale

Excessive convexity tends to produce notch effects in multipass welds, and may lead to other weld faults, such as slag inclusions, lack of fusion and porosity, when depositing subsequent passes.

The term *Convexity* is normally referred to the profile of a fillet weld (Fig. 9), whereas *Excessive Weld Reinforcement* is referred to the profile of a groove weld as illustrated in Fig. 10.



*Fig. 9 – Excessive Convexity in a
Fillet Weld*



*Fig. 10 – Excessive Reinforcement in a
Groove Weld*

Excessive Convexity, like *overlap*, may be caused by inhibited weld metal fluidity. Typical causes of convexity may be one, or a combination of the following:

- *Improper Techniques*

- Travel Speed too slow
- Incorrect Electrode angles
- Incorrect weave techniques

- *Essential Variables*

- Insufficient electrode diameter
- Insufficient amperage and voltage

- *Joint Preparation Contaminants*

- Oil
- Paint
- Rust
- Mill Scale

Excessive Weld Reinforcement is associated with groove welds and is undesirable since it tends to stiffen the section at that point as well as establish notches. This condition results from improper welding technique, or insufficient welding current, and is shown in Fig. 11. This fault is often connected with some irregularity in weld profile and is illustrated in Fig. 12. The opposite of this defect is insufficient reinforcement in the groove weld like that shown in Fig. 13.

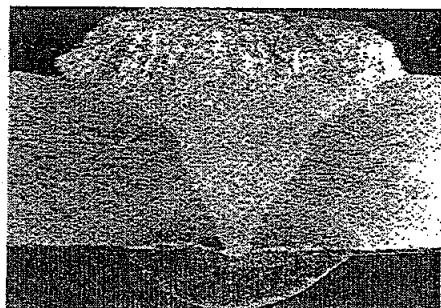


Fig. 11 — Excessive Weld Reinforcement

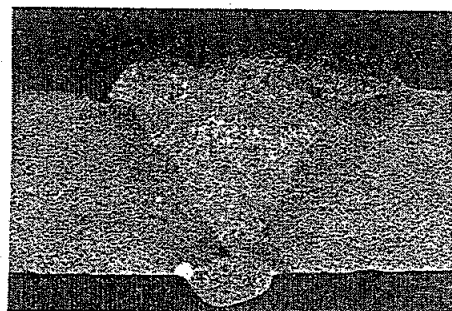


Fig. 12 — Irregular and Excessive Reinforcement in Single V Butt

Codes, Specifications and Standards limit the amount of reinforcement on groove welds and should be followed accordingly.

Insufficient Weld Reinforcement, also associated with groove welds is considered undesirable. The effective Load Capacity is reduced considerably, if not properly corrected. As illustrated in Fig. 14, additional passes should be added to bring the weld to a proper size; but, care should be taken when applying additional passes to:

- Maintain proper profiles.
- Not exceed reinforcement requirements.
- Not create additional weld faults.

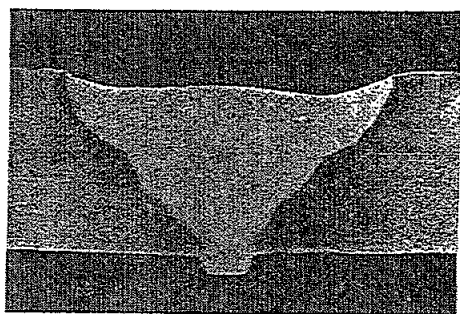


Fig. 13 — Insufficient Face Reinforcement

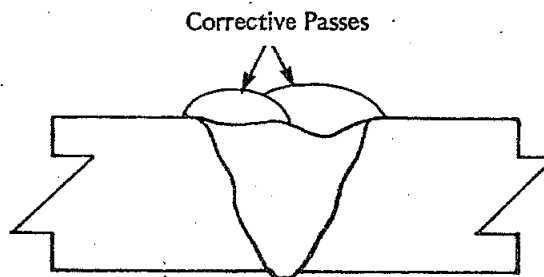


Fig. 14 — Correction for Insufficient Reinforcement

Undercut

This term describes the melting away of the parent material during the welding process. If undercutting is not corrected, it may be detrimental to the component and is, therefore, a fault.

Undercut can occur at any stage of the welding process, for example:-

- Root undercut in a single Vee Butt Weld without back welding (Fig. 15).
- Undercutting of the sidewall of a welding groove at the edge of a layer or bead, thus forming a sharp recess in the sidewall at a point where the next layer or bead must fuse (Fig. 16).
- Reduction in base metal thickness at the line where the last bead is fused to the surface (Fig. 17 – external undercut).

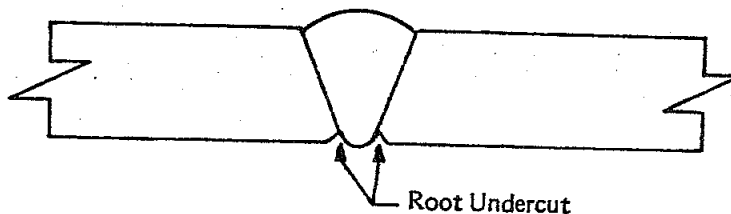


Fig. 15

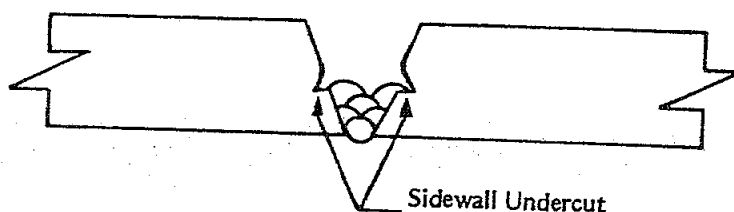


Fig. 16

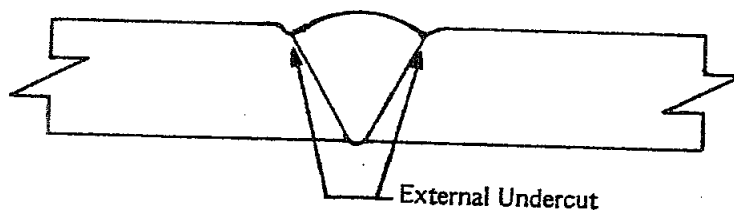


Fig. 17

Undercutting of the side walls of a groove does not affect the completed weld if sufficient care is taken to correct the condition before depositing the next bead. Failure to correct the condition may lead to slag being trapped in the cavity during the welding of the next pass. Surface undercutting, both internal and external, should be corrected. However, some construction codes and standards allow limited amounts of undercut to remain in the weld. For example, CSA Standard W59 paragraph 5.9.5 and AWS D1.1-80 paragraph 9.25.1.5, state that undercut shall not be more than 0.010 inch (0.25 mm) deep when the weld is transverse to the primary stress in the part that is undercut. They further state that undercut shall be no more than 1/32 inch (0.8 mm) deep when the weld is parallel to the primary stress in the part that is undercut.

On the other hand, the designer may specifically state in a product specification that undercut in any degree is not allowed.

Some of the probable causes of undercut are as follows:—

- *Operator Technique.* Too much current on too long an arc may increase the tendency to undercut.
- *Electrode.* Different types of electrodes show varying characteristics in this respect.
- *Joint Accessibility and Position.* With some electrodes the most skilled operator may be unable to avoid undercut under certain conditions such as accessibility and position.
- *Joint Preparation.* Inadequate root face may cause excessive *internal* undercut (Fig. 18).

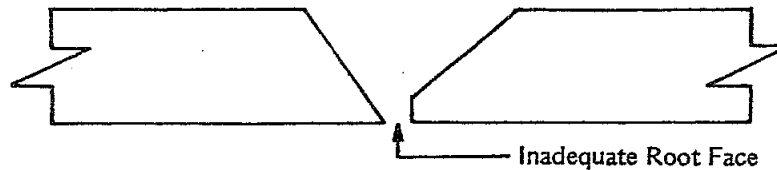


Fig. 18

Excessive Concavity may occur in the root pass of a groove weld (Fig. 19), but is more often associated with fillet welds. It should be noted that drawings may call for concave fillet welds, in which case it would not be considered a weld fault. The size of a concave fillet weld is determined by its throat size, not the actual measurement of its leg length. It should be noted that a concave fillet profile is dependent on service conditions.



Fig. 19 — Concavity

As illustrated in Figs. 20 & 21, it must be noted that an excessively concave weld profile gives a deceptive appearance as to its actual size. Fig. 22 indicates corrective action for concave fillet welds.

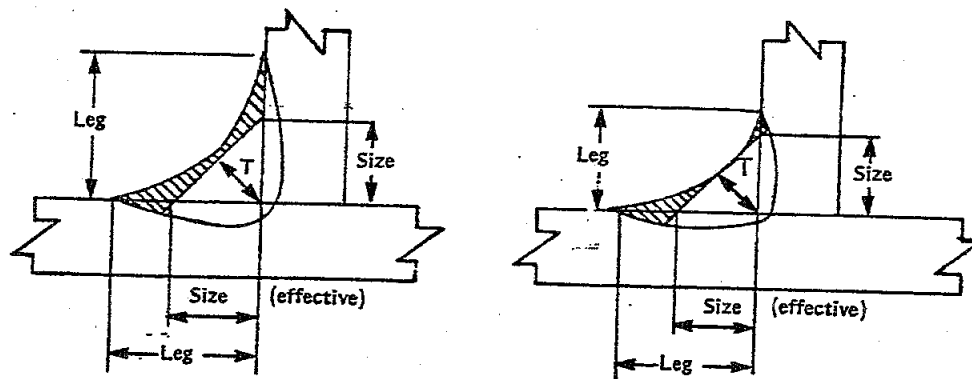


Fig. 20 — Concave Fillets

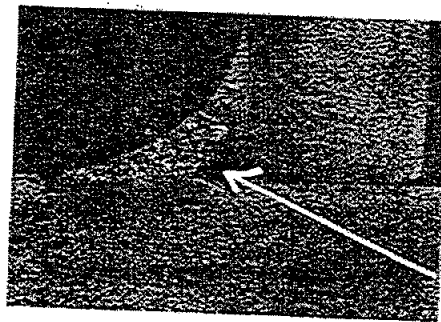


Fig. 21 — Excessive Concavity

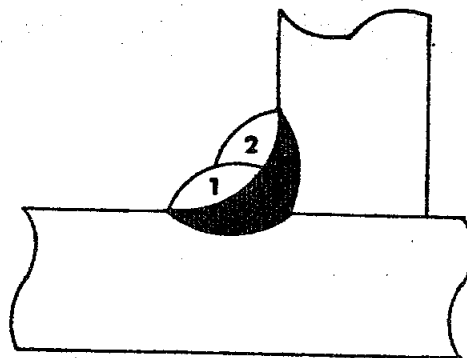


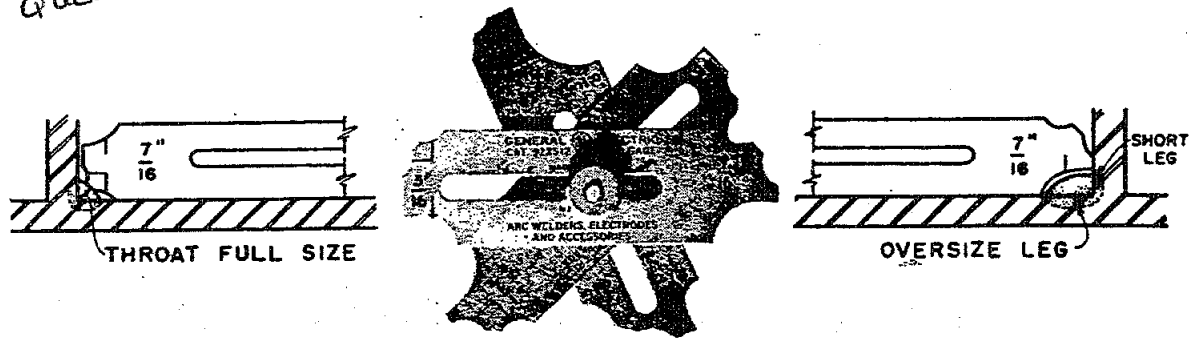
Fig. 22 — Corrective Passes for a Concave Fillet

Insufficient weld reinforcement may be caused by any one or a combination of the following operator manipulation techniques:

- Travel speed too fast.
- Insufficient passes or layers.
- Incorrect weave techniques.
- Excessive included groove angles.

Weld deficiencies due to insufficient or excessive size and poor profile may be detected by visual examination, or by the use of suitable gauges as illustrated in Fig. 23.

* HAS BEEN TEST
QUESTION BEFORE



Six-bladed pocket size fillet weld gauge and methods of use

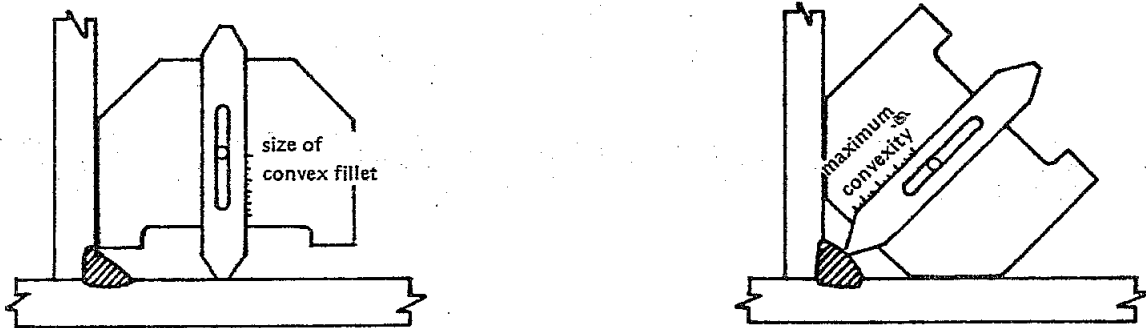


Fig. 23 – Multi-Purpose Welding Gauge

Typical causes of concavity can be divided into the following categories:-

- Incorrect operator manipulation
- Change in the essential variables
- Inadequate joint geometry
- Position of welding
- Process behaviour
- Material type

Each of these categories may be sources contributing to concavity either individually, or in combination.

Incorrect Profile and Size of Lap Weld

The exposed corner of the upper base plate is melted off along the length of the weld, reducing the length of the vertical leg and consequently the designed throat size of the weld, as illustrated in Figs. 24 & 25.

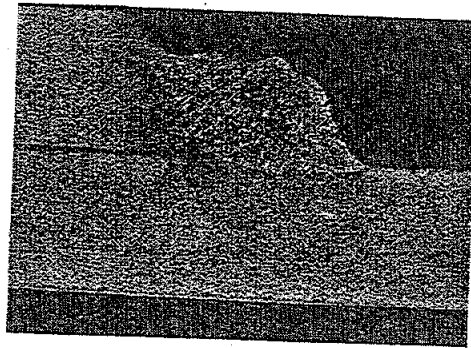


Fig. 24 — Section Showing Actual Weld Size with Reduced Throat Thickness

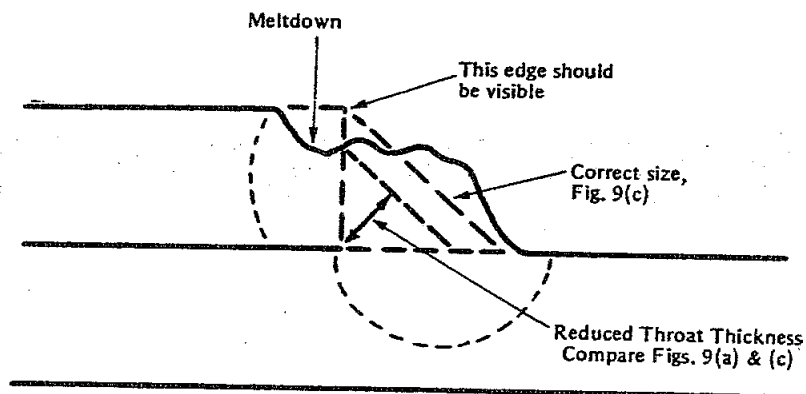


Fig. 25 — Reduction in Throat Thickness

The upper edge should just remain visible, or, failing this the weld fault should be corrected by the addition of another weld pass as illustrated in Figs. 26 & 27.

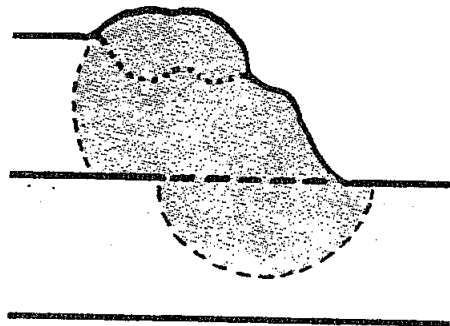


Fig. 26 — Restoration to Correct Size by Addition of a Weld Pass

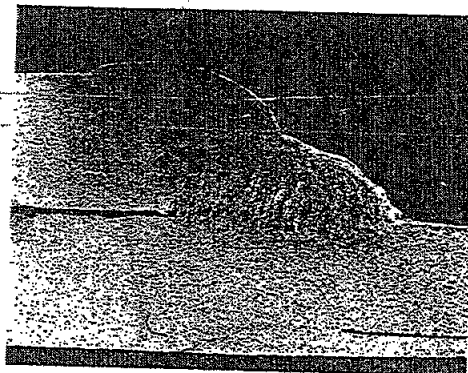


Fig. 27 – Restoration to Correct Size

Melting the upper edge may be caused by:

- Inadequate operator manipulation
- Process Behaviour
- Essential Variables
- Material Type
- Position of Weld
- Inadequate Joint Geometry

Proper manipulation by the operator is usually determined by the above mentioned categories and may be the cause of the weld fault. Each of the above categories may contribute to the operator technique.

Out of Line Weld Beads

Cause

Insufficient care in positioning automatic welding machines, or careless chipping out of the back side of welds, so that the groove is displaced from the root of the weld, can lead to the misalignment of the weld.

Structural Faults in the Weld Zone

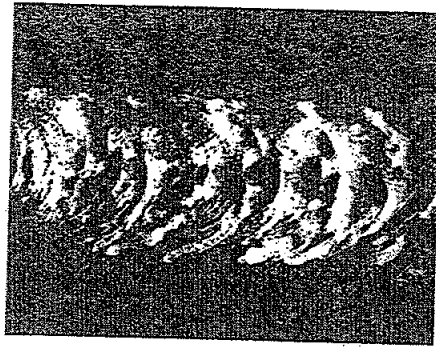
Gas inclusions (porosity)

- Isolated gas holes
- Worm holes (elongated gas holes)
- Piping
- Hollow root
- Scattered porosity
- Grouped porosity
- Christmas tree porosity

Inclusions

- Isolated slag inclusions
- Slag lines
- Slag entrapment behind backing strip
- Slag inclusions missed by back gouging (double V weld)
- Tungsten inclusions
- Copper inclusions (from carbon arc-air operations)
- Slag from laminations in parent material

The term porosity is used to describe gas pockets entrapped within the weld metal. Porosity may manifest itself in a variety of patterns, sizes, shapes and quantities. Porosity may be present in any position in the deposited weld metal. Some porosity may appear on the surface of a weld, and, therefore can be detected visually. However, when the porosity is sub-surface, special testing such as radiography is necessary to disclose it. Examples of porosity are illustrated in Figs. 28, 29, 30 & 31



*Fig. 28 — Severe Surface Porosity
(sulphur or moisture)*

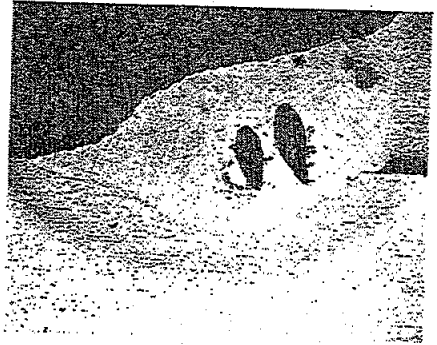


Fig. 29 — Severe Piping in Lap Weld

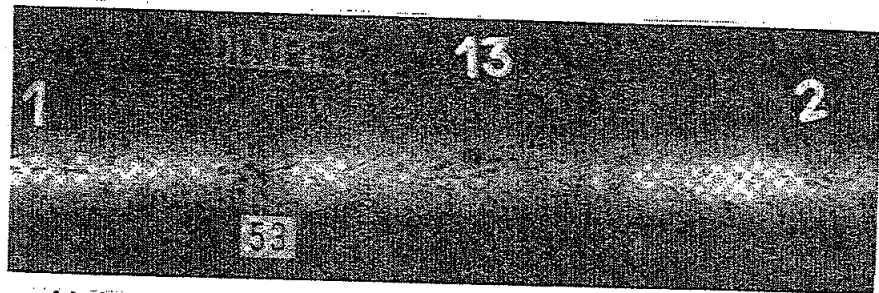


Fig. 30 — Radiographic image of Porosity resulting from use of wet basic electrodes

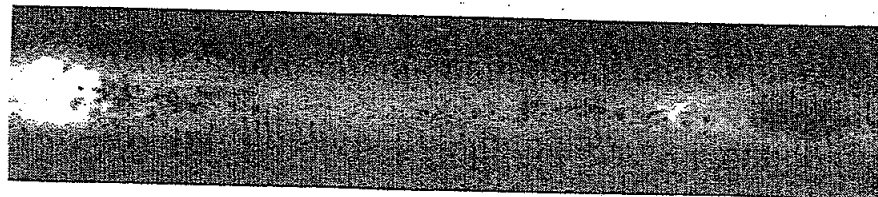


Fig. 31 — Radiographic image of Porosity in submerged arc welds.

Causes of Porosity

In multipass welding, the location of porosity in relation to the depth over the cross-sectional area of the weld may assist in determining the probable cause.

In many cases porosity is accumulative as subsequent passes are deposited. In order to preclude building up the density of the porosity to a point where a completed weld would be unacceptable, it should be removed entirely prior to the addition of further passes.

The probable basic causes may be categorized as follows:

- a) Moisture.
- b) Chemistry & structure of the parent material.
- c) Surface impurities and contaminants.
- d) Faulty electrodes, fluxes, shielding gases, slag.
- e) Operator techniques.

Moisture

Moisture pick-up in flux coated electrodes or flux-cored wire will cause porosity. The same situation pertains to externally applied flux in welding processes such as submerged arc and electroslag.

In order to avoid moisture, the consumables should be stored under controlled conditions. Various codes and standards may require procedures for the proper storage of weld consumables, such as CSA Standard W59 and AWS D1.1.

Parent Material

It is important to select the properly matched filler metal to match the chemistry of the material to be welded. In cases of relatively high sulphur content, porosity is commonly encountered. Other elements, such as zinc in galvanized steels, may also create excessive porosity after welding.

Materials with dense oxides, such as aluminum, should be carefully cleaned or porosity may occur. Laminations in plate may also be a source of porosity in the welding operation.

Surface Contaminants

When fabricating metals, the surfaces may be in contact with certain contaminants which can cause porosity. Some of these contaminants are as follows:

- Oil
- Grease
- Paint
- Oxides.

Rust and mill scale are also probable sources of porosity.

Methods of preparing material for welding often introduce contaminants, and some of these methods are:

- Shears
- Band saws
- Abrasive Grinding Wheels
- Mechanical Nibblers
- Oxy-Fuel Apparatus

Malfunctioning tools, such as air grinders, air chipping tools or air scaling guns, may deposit films of oil or grease on the surfaces to be welded.

Where aluminum is being welded, tools used on other materials such as steels, may introduce contaminants which will cause porosity.

Carbon steel wire brushes used on stainless steels may also be a cause of porosity.

Contaminants which cause porosity may be picked up during recovery operations of infused flux during or after submerged arc welding operations.

Insufficient Flux Coverage

Insufficient flux covering in submerged arc welding may be a cause of scattered surface porosity.

Slag Residue

Slag left on the surface of tack welds may cause porosity.

Shielding Gas

Porosity associated with shielding gases is often caused by poor distribution within the arc and surrounding areas, or impurities collected in the gas through hoses, connections, and the torch or gun assemblies. As an example.

When setting up for GMAW of aluminum, using pure argon, hoses, regulators and cables (which have been used exclusively for welding steel with CO_2 or CO_2 mixtures) will be a possible source of contamination and subsequent porosity if they are not replaced or cleaned properly.

Loose fittings and connections may allow atmospheric gases to enter the gas hoses and assemblies and cause porosity.

As illustrated in Fig. 32 upon welding an outside corner with GMAW, .035 E70S6 and Ar CO_2 Shielding, a gas nozzle inner diameter exceeding 13 mm (1/2") could cause porosity.

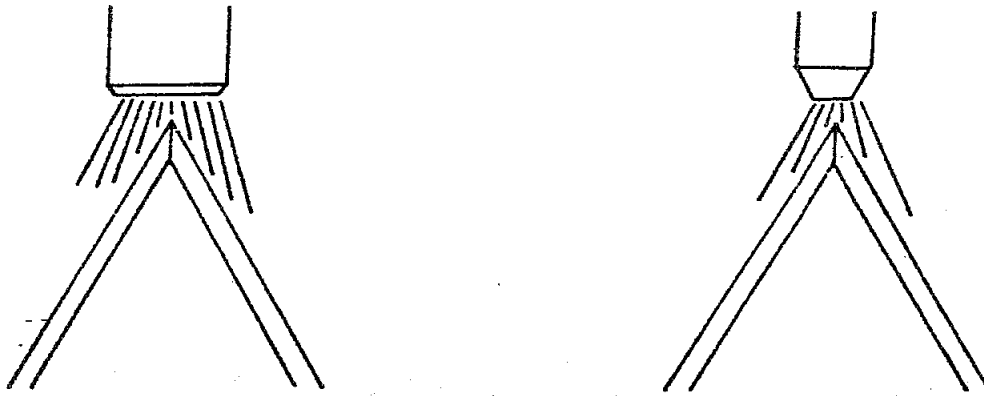


Fig. 32

If the distance the cup is held from the work is incorrect, it may cause porosity (i.e., 3/4" is acceptable and 1 1/2" is not acceptable).

Operator Techniques

In manual welding applications, the following may cause porosity:

- a) Faulty manipulation of the electrode.
- b) Excessive arc voltages.
- c) Incorrect electrode angle.
- d) Incorrect weave techniques

Slag Inclusions

This term is used to describe oxides and other non-metallic solids which are sometimes found as elongated or multifaceted inclusions in welds.

Slags are always produced when welding with covered electrodes, and they serve as scavengers of impurities in the molten metal pool. In addition, they form a blanket over the weld to control the cooling rates and exclude atmospheric oxygen from the hot metal surface.

During the welding process, slag is formed and forced below the surface of the molten metal by the stirring action of the arc. Slag may also flow ahead of the arc causing the metal to be deposited over it. In any case, it tends to rise to the surface because of its lower density.

A number of factors may prevent its release and result in the slag being trapped in the weld metal. Some of these factors are.—

- a) High viscosity of weld metal
- b) Rapid solidification
- c) Too low a temperature
- d) Improper manipulation of the electrode
- e) Undercut on previous passes

One other potential cause of slag is foreign material entrapped in laminations in the weld bevels.

In multi-pass welding, insufficient cleaning between weld passes can leave portions of slag coating in place to be covered by subsequent passes. Such slag inclusions are often characterized by their location at the edge of the underlying metal deposits, where they often tend to extend longitudinally along the weld.

In making a root pass the electrode may be so large that the arc strikes the side of the groove instead of the root. The slag will roll down into the root opening and may be trapped under the metal of the root layer because the arc failed to heat the bottom of the root to a sufficiently high temperature to allow the slag to float to the surface.

Slag lines are formed either intermittently or continuously. If the prior pass produces a bead which is too convex, or if the arc has undercut the bevelled wall, it will be difficult to remove the slag remaining in the angle between the surface of the groove and the deposited metal. When the slag is left in place it is covered by subsequent passes (Fig. 33).

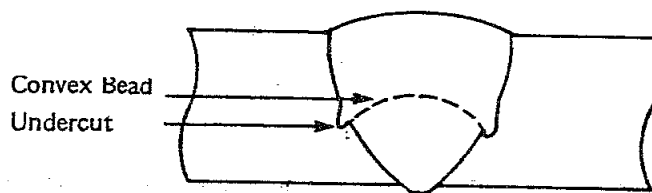


Fig. 33

The majority of slag inclusions may be prevented by proper preparation of the groove before each bead is deposited, using care to correct the contour which would be difficult to penetrate fully with the arc.

Tungsten Inclusions

Tungsten inclusions are characteristic of the inert atmosphere welding methods. If the tungsten electrode which supports the arc comes into contact with the weld metal, some tungsten particles are trapped in the deposited metal. These may be in the form of small pieces of the tungsten wire. Due to its high melting point, fusion of the tungsten to the deposited weld metal does not occur.

Copper Inclusions

This type of inclusion occurs when pieces of the copper sheath of a carbon arc-air electrode fall into the groove and are subsequently welded over.

Another cause of copper inclusion may occur when magnetic particle testing of welds is done. The current for the magnetic field may be passed through copper conductors (*prods*). If there is poor contact of the prods to the steel when the current is applied, sparking will occur between the prods

and the steel, and copper particles may be melted into the weld structure. This type of problem should be carefully controlled due to the propensity to crack propagation from the embedded inclusions.

Oxidation

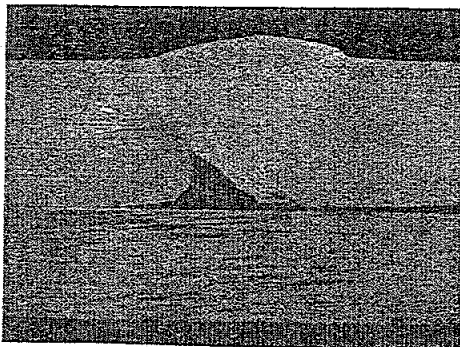
In pipe and tube welding of components for critical service, (i.e., nuclear plant) some specifications forbid the presence of oxides on the internal surface of the welds. In these cases, the internal surface of the pipe/tube is purged with a constant supply of inert gas. If the gas flow is inadequate, oxides will form and cause the weld to be rejected. Control of the gas supply is, therefore, an essential operation to produce sound welding.

Fusion Faults

- Lack of fusion (insert)
- Lack of sidewall fusion
- Lack of root fusion
- Lack of fusion in fillet welds
- Underbead non-fusion / Cold Lap
- Incomplete penetration

Lack of Fusion

The term is used in this instance to describe the failure to fuse weld metal to the base material, or adjacent layers of weld metal to each other. Failure to effect fusion may occur at any point in the welding groove or fillet weld as illustrated in Figs. 34, 35, 36, 37, 38 and 39.



*Fig. 34 – Lack of fusion at root of open square butt on backing bar
Also lack of penetration*

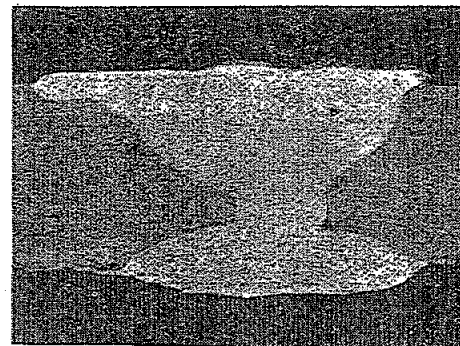
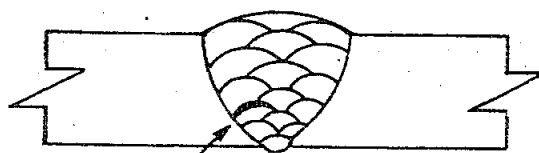
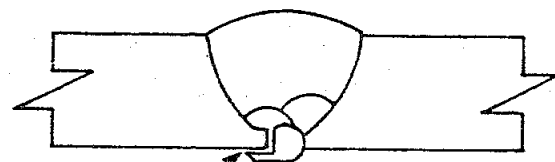


Fig. 35 – Lack of fusion at root of open square butt, welded both sides



Underbead Non-Fusion / Cold Lap

Fig. 36



Unfused Insert

Fig. 37

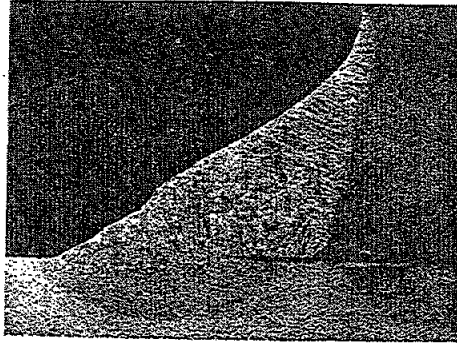


Fig. 38 — Lack of Fusion at Root of Fillet

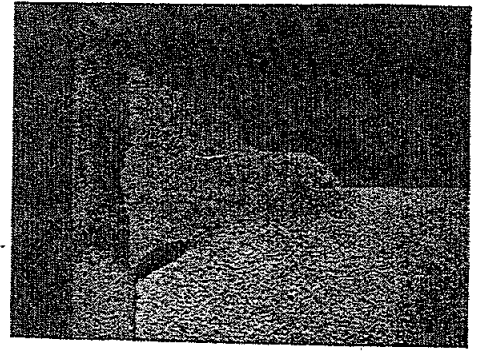


Fig. 39 — Lack of Fusion at Root of J Weld in Thick Section

Lack of fusion may be caused by a number of factors, either singly or in combination. Some of these factors are listed below:

- a) Using too large an electrode for a narrow Vee.
- b) Using wrong type of electrode.
- c) Insufficient welding current, resulting in failure to raise the temperature of an adequate amount of base material to the melting point.
- d) Improper manipulation of the electrode.
- e) Failure to dissolve, by proper fluxing, the oxides or other foreign materials on the surfaces to which the weld metal must fuse.
- f) Poor joint design. As an example, a narrow Vee groove in a thick plate would limit manipulation of the electrode. This would increase the probability of non-fusion of the weld metal to the parent metal (Fig. 40).
- g) Inadequate shielding gas (if used).

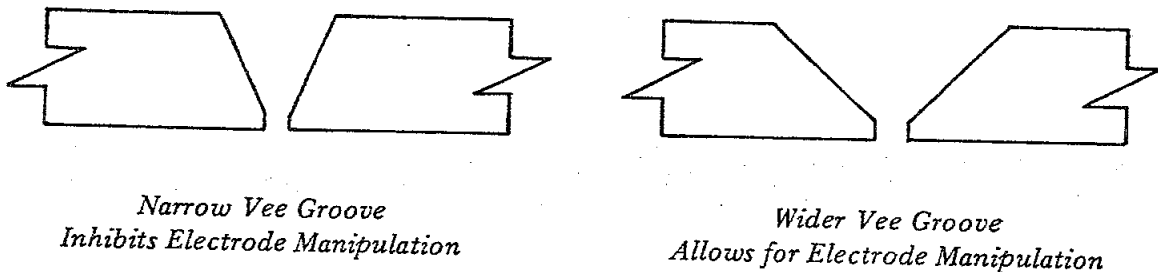


Fig. 40

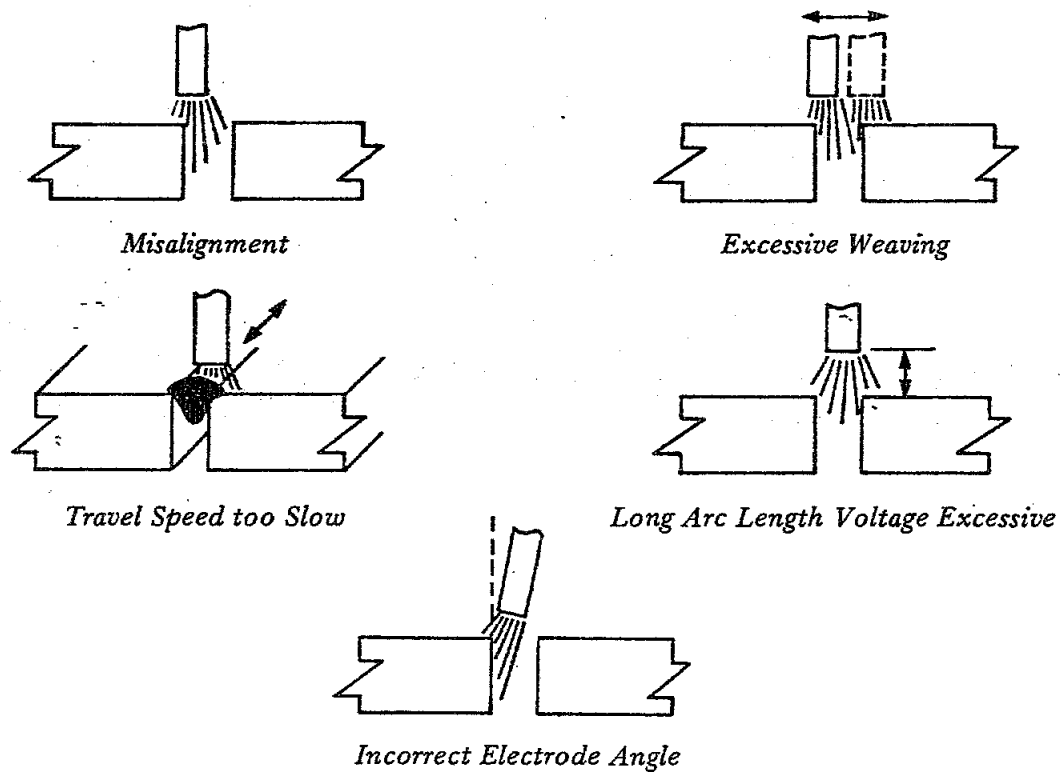


Fig. 41 – Operator Techniques

Incomplete Penetration

The term incomplete penetration describes the failure of the deposited weld metal to fuse integrally with the parent material at the root of the weld joint (See Fig. 42).

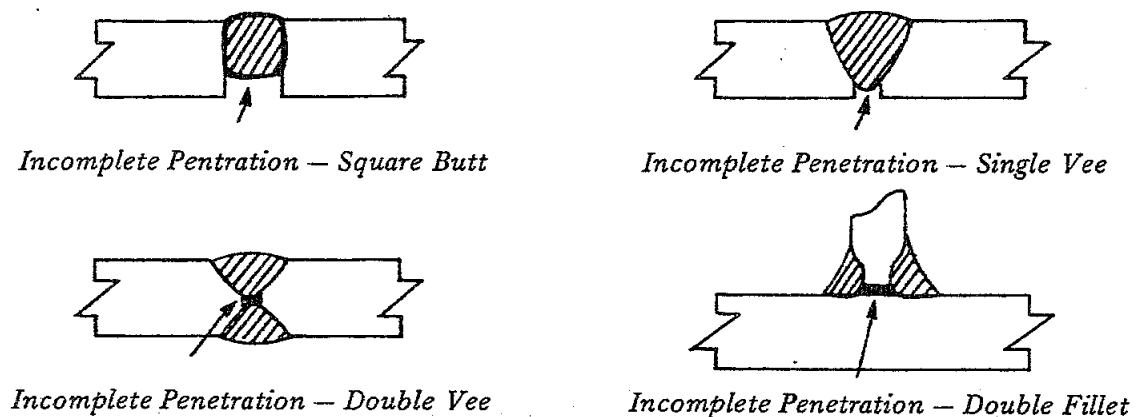


Fig. 42

It must be noted that incomplete penetration is not necessarily a weld fault, indeed, some welded structures are designed with incompletely penetrated welds. Incomplete penetration becomes a weld fault when the codes, specifications and designs require complete penetration.

The causes of incomplete penetration are very similar to those causing lack of fusion, and are listed below.

- a) Using too large an electrode for a narrow Vee.
- b) Using the wrong type of electrode.
- c) Insufficient welding current, resulting in failure to penetrate and fuse the root face.
- d) Improper manipulation of the electrode (Fig. 41).
- e) Poor joint design.
- f) Poor fit-up causing inadequate gap between the root faces.

Cracking

Solidification Cracking

During the solidification of weld metal, grains begin to grow from the fusion boundary towards the central region of the weld pool.

Some alloying elements and impurities are rejected ahead of the growing crystals. Their presence lowers the freezing temperature substantially below that of the first liquid to solidify. As solidification takes place, the weld and surrounding material are progressively cooling, and this gives rise to contraction strains across the weld.

When solidification is almost complete, and grains begin to meet, the low melting point liquid may lead to such low ductility that the contraction strains produce cracking.

Hot Cracks

The development of "hot-cracks" in welds results from the combined effects of metallurgical and mechanical factors. Some metals are prone to hot-cracking, e.g., high temperature alloys and high sulphur steels.

Hydrogen Induced Cold Cracking

Cold cracks may occur in the weld metal or in the heat affected zone. Cold cracks in the weld metal may occur in any orientation with respect to the weld axis, but the commonly observed positions are illustrated in Fig. 43.

Transverse cracks in the weld metal may extend into the heat affected zone of the parent plate and beyond.

HAZ cracks are usually longitudinal and most often occur at the root or the toes of the welds. Under some conditions *longitudinal cracks* may be very long, sometimes running the entire length of the weld.

Cold cracking may also manifest itself as fine micro-cracks difficult to detect by normal inspection and non-destructive test methods. The presence of micro-cracks may be symptomatic of a more serious condition (such as high hydrogen level) that could lead to more serious cracking.

Figs. 43, 44 and 45 show typical cold cracking and commonly observed positions. As the name implies the cracks form at low temperatures — generally below 200°C. In most cases, cracks occur at room temperature when the weld has completely cooled.

Cold cracks are often delayed. Even after the joint has cooled to room temperature, there may be a further lapse of time before cracking occurs. This may be a few minutes or several hours, although in some extreme cases cracks have been observed to form several months after welding.

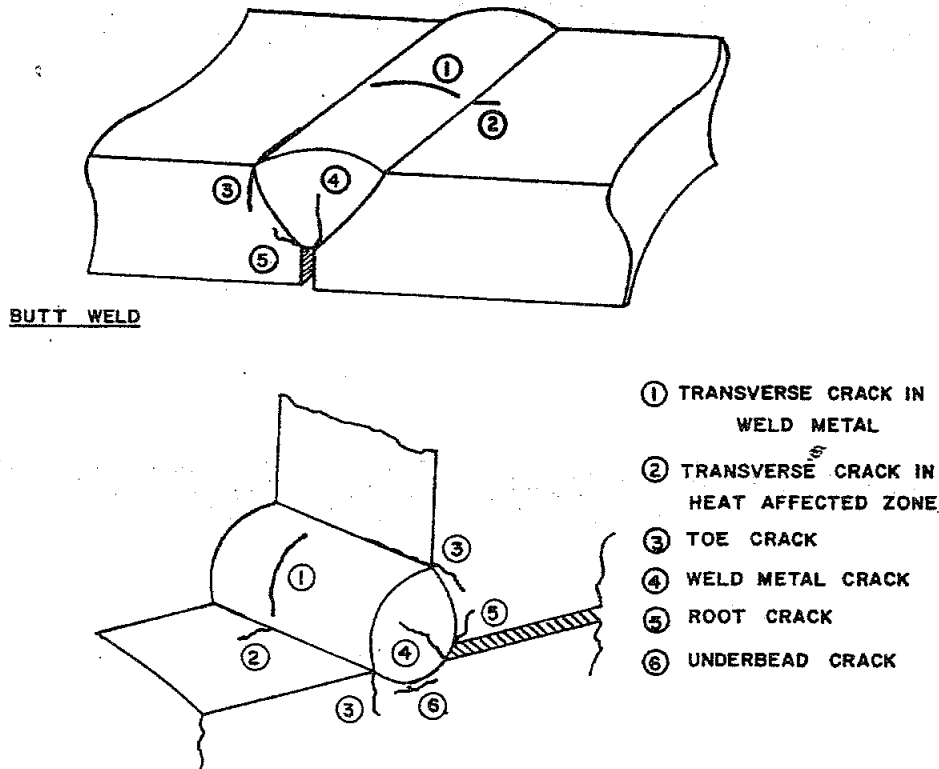


Fig. 43 — Commonly observed positions of cold cracks in butt and fillet welds.

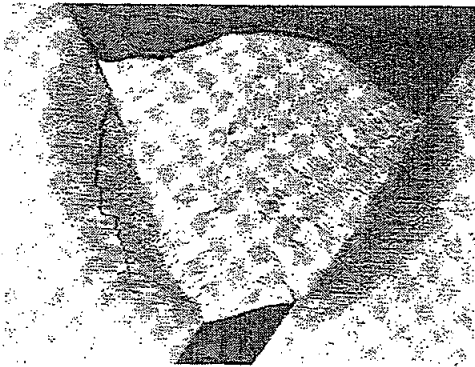


Fig. 44 — Typical cold crack in the affected zone.

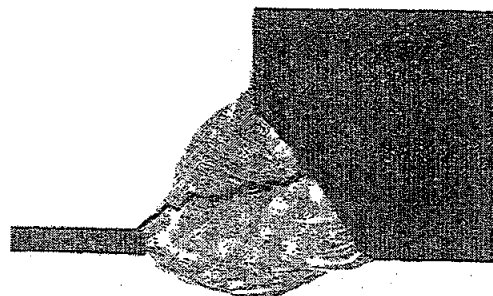


Fig. 45 — Typical cold crack in weld metal.

The causes of hydrogen induced cold cracking are complex and cannot be fully documented in this text, however, a brief list of some of the causes is as follows:

- Hydrogen from coated electrodes
- Hydrogen from external sources in the base material, i.e., Hydrogen Sulphide
- Insufficient pre and post weld heat treatment.

Tack welds left for inclusion in the completed weld may be the cause of cracks. If the tack weld is made on a completely cold surface of a large mass compared to the size of the tack, the result is a rapid quench, and if the tack is badly made, or of insufficient size, a crack may readily occur.

Crater cracks occurring during solidification are more likely to form in a long crater, Fig. 46 (a), where the columnar crystals form from each side of the joint, at right angles to the axis of the weld. Thus leaving a plane of juncture subject to cleavage as the metal shrinks. A short crater displays columnar crystals radiating from the centre as shown in Fig. 46 (b).



Fig. 46

Figs. 47, 48, 49, 50, 51, 52, 53 & 54 illustrate a variety of weld and HAZ cracks.

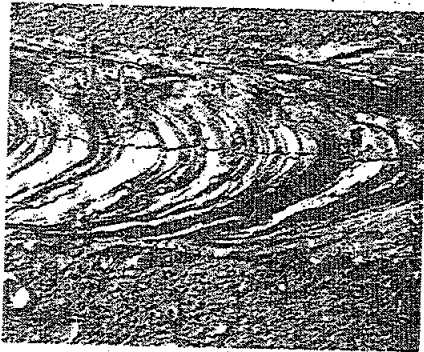


Fig. 47 – Longitudinal Crack in Butt Joint

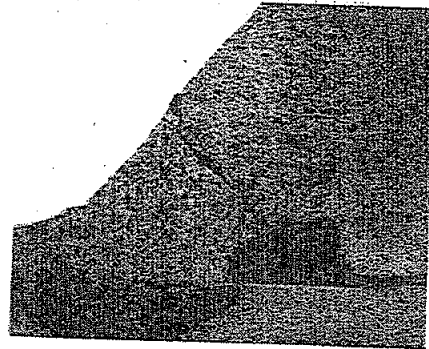


Fig. 48 – Crack in Fillet - Lack of Penetration

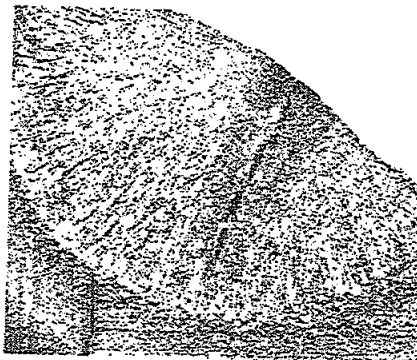


Fig. 49 – Hot Crack in Deep-Penetration Fillet

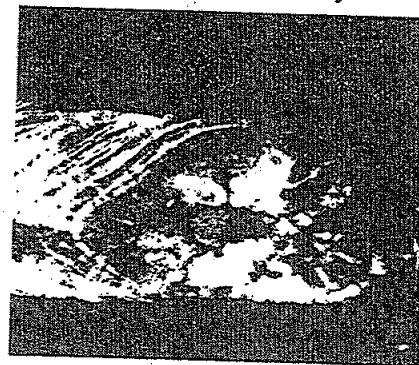


Fig. 50 – Crater Cracks in Fillet

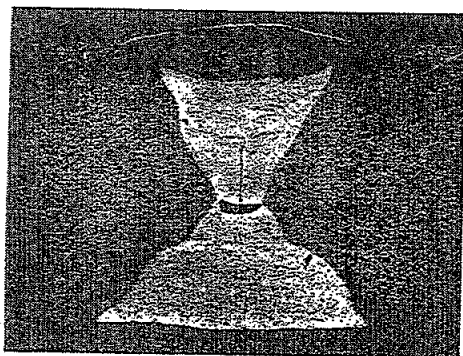


Fig. 51 — Root Crack in First Pass of Double V-Butt



Fig. 52 — Root Crack in Thick U Butt

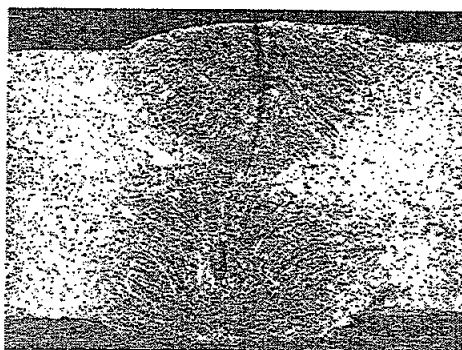


Fig. 53 — Cracks in Close Square Butt, Associated with Slag Inclusion

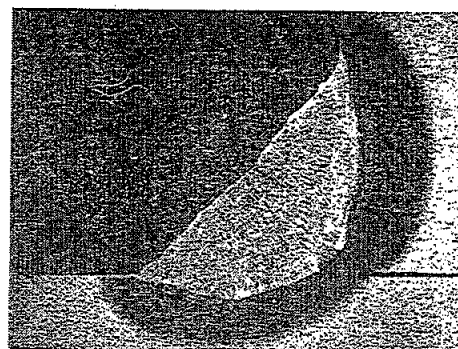


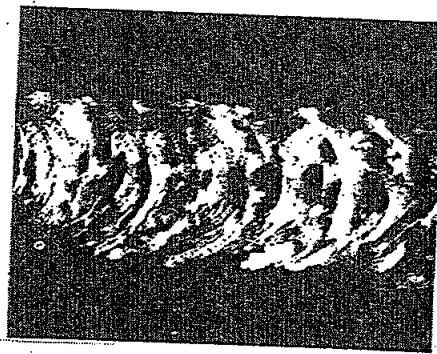
Fig. 54 — Heat-affected Zone Crack in Low-Alloy Steel (Underbead Crack)

Some of the causes of cracking are listed below:

- 1) Hydrogen content of electrode
- 2) Hydrogen impregnation of the parent material
- 3) High sulphur content of the base material
- 4) High carbon content of the base material
- 5) High restraint on the joint
- 6) Rapid cooling of hardenable and brittle material
- 7) Welds too small for the size, rigidity and quenching effect of the parts joined
- 8) Poor joint fit up
- 9) Unsuitable electrodes
- 10) Secondary faults such as lack of penetration, porosity, elongated craters, etc.

Surface Defects (irregularities)

Sometimes conditions are encountered during welding which result in holes in the surface of the deposit (see Fig. 55). This is generally considered the result of a highly reducing atmosphere. Such a condition is most likely to be encountered at the bottom of a narrow groove where the air is completely excluded and no normal reaction takes place between the arc atmosphere and the surrounding air. The base metal being welded can be a factor (sulphur, moisture in both base metal and electrode, as mentioned before) but leaving this out of consideration, improvement is usually obtained by changing the electrical conditions such as current and polarity. Often an increase of arc length will correct this condition, but it may be necessary to change the type of electrode.



*Fig. 55 — Severe Surface Porosity
(sulphur or moisture)*

Unsatisfactory Surface Appearance and Spatter

The following illustrated surface irregularities should be noted:

- Fig. 56 — badly shaped surface ripples
- Fig. 57 — badly shaped ripples and excessive spatter
- Fig. 58 — an inadequately filled crater
- Fig. 59 — an overly filled crater
- Fig. 60 — (a) and (b) — stray flash (accidental striking of arc on plate, adjacent to weld)

The operator is usually directly responsible for these defects as a result of incorrect technique or improper machine settings. Sound welding finished in a poor manner should not be excused even though the adequacy of the joint is beyond doubt. The ability and integrity of the operator must be questioned.

In some cases, faulty or wet electrodes and unsuitable base material (high sulphur, for example, as mentioned before) may cause similar defects and unsatisfactory weld appearance.

Bead irregularities are defects inasmuch as they constitute an abrupt change of section. Spatter in itself is not necessarily a defect, but is quite likely indicative of improper welding and the likelihood of other associated faults.

Stray flashes either with the electrode or holder are more serious than might at first be expected. They create a quenched and brittle condition in alloy steels and are inadvisable even on mild steel, where high static or normal fatigue stresses may be encountered. The repair of such damage may be difficult and costly, involving chipping and probably preheating in the case of alloys.

UNSATISFACTORY SURFACE APPEARANCE, SPATTER, STRAY FLASH

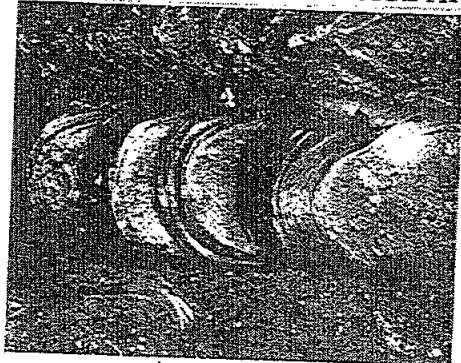


Fig. 56 — Badly Shaped Ripples

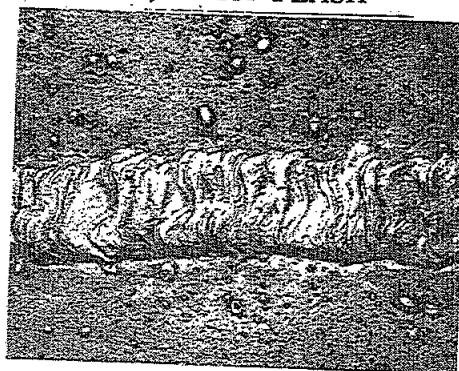


Fig. 57 — Spatter and Badly Shaped Ripples

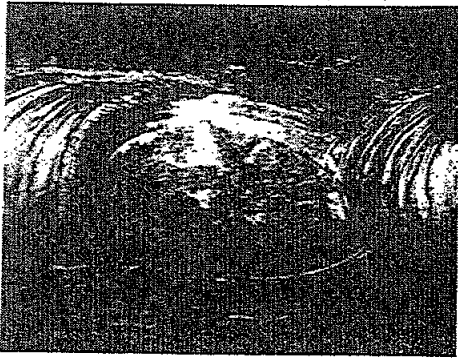


Fig. 58 — Bad join. Crater not filled

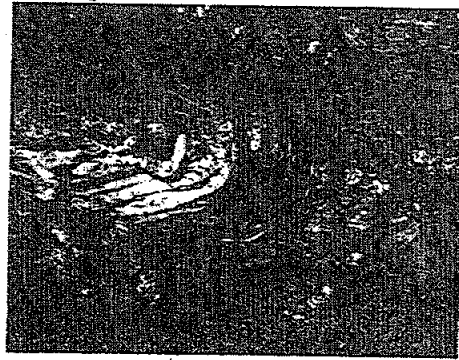


Fig. 59 — Bad Join. Excessively Filled Crater

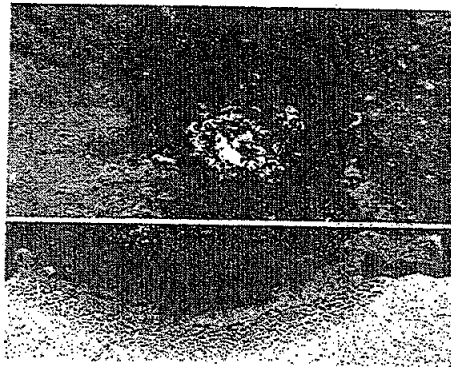


Fig. 60 — (a) and (b)

Electrode holder stray flash (a), cross section (b) accidental striking of arc on plate, adjacent to weld. Danger: cracks in low alloy steels and stress raiser under fatigue loading

Defective Properties (Weld Metal and Joint)

Specific mechanical and chemical properties are required of all welds made in any given weldment. These requirements depend on the codes or specifications involved and departure from specified requirements is considered a defect. These properties are generally determined with specially prepared test plates but may be made on sample weldments taken from production. Where test plates are used, the inspector should see that specified procedures are followed, otherwise the results obtained will not necessarily indicate the actual properties of the weldments.

Mechanical properties which may be defective are tensile strength, yield strength, ductility, hardness and impact. Chemical properties may be deficient because of incorrect weld metal composition or welding procedure. Both may result in lack of corrosion resistance.

Not all these defects are due to improper welding conditions since many such difficulties are caused by the base metal. Properties of the base metal which may not meet the requirements are chemical composition, internal conditions (laminations and stringers), surface conditions (mill scale, grease, paint, oil, etc.), mechanical properties and dimensions. All these factors should be kept in mind when considering the causes of welding difficulties.

SUMMARY OF WELD FAULTS

A good inspector can, and will assist greatly in preventing faults in welding. As an aid to competent inspection, the following summary lists a number of defects which are likely to occur under certain welding conditions:

Welding Conditions	Effects Likely to Occur
a) Cold weather	Cracks in weld or base metal
b) Thick or rigid assemblies	Cracks in weld or fusion line
c) Hardenable materials	Cracks in either weld or base metal
d) Base material known or suspected high in sulphur content (free machining steels for example)	Cracks and porosity in weld
e) Rusty, oily or greasy joints	Porosity, inclusions and lack of fusion
f) Limited access to joint	Undercut, particularly if welding in vertical or overhead position
g) Welding in corners, at ends of weld and first passes in deep groves	Arc blow, resulting in poor fusion, porosity, incomplete penetration, spatter and poor appearance.

GUIDES AND EXERCISES

MODULE 10

WELD FAULTS AND CAUSES

WELD FAULTS AND CAUSES

MODULE 10

Guides & Exercises

To obtain maximum benefit from this module we suggest that you follow this guide and complete the exercises as indicated. It is important that you work through the text methodically, studying each section thoroughly before moving on. The exercises are designed to give you an indication of whether you have learned the material and can move on or whether you need to go back and study the section again.

Do the exercises honestly. They will not help you unless you take them seriously. If you get a question wrong go back through the text until you understand where you have gone wrong and know the correct answer.

The length of time required to complete the module will vary from student to student. Find your own pace. Do not rush. Remember you are trying to teach yourself something, not win a race.

Some people like to underline sections when they read a text. We suggest that you use caution if you do this. What you think is important first time you read it may be different after reading it three times. We suggest you read a section three times thoroughly before highlighting anything.

The last exercise is designed to give you an indication of whether you are ready to take the WIC closed-book exams. The exercise questions are of a similar standard to the official exams. Do not take the exam until you feel you are ready and you may wish to study several Modules before taking the exams on each. The details of the examination procedures are on a separate sheet.

If you have any difficulties with this Module do not hesitate to ask for help. You may find you learn more by attending some of the seminars and you should also contact your local WIC Chapter to see if they can be of assistance. Remember, if you fail the examination you can always try again later.

MODULE 10

Guide 1

Carefully read pages 2 to 5 and answer the following questions:

1. From the following list check off those which are dimensional faults prior to welding:
 - a) Incorrect root openings
 - b) Insufficient leg
 - c) Overlap
 - d) Incorrect root face
 - e) Incorrect bevel angles
 - f) Insufficient throat

2. In CSA Standard W59-1977 and AWS D1.1-80 a groove angle specified on a drawing as 60° should be between:
 - a) 45° and 60°
 - b) 55° and 70°
 - c) 55° and 65°
 - d) 60° and 70°

3. CSA Standard W59 limits irregularities on surfaces to be welded. Complete the following sentence:

Occasional notches not more than inch deep, on otherwise satisfactory surfaces shall be removed by machining or grinding.

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 10

Guide 2

Carefully read pages 6 to 10 and answer the following questions:

1. From the following list check off those which are dimensional faults after welding:
 - a) Distortion
 - b) Incorrect fit-up
 - c) Irregularities in the surfaces of the joint preparation
 - d) Overlap
 - e) Insufficient throat
 - f) Convexity
2. One of the typical causes of overlap is contamination of the joint preparation. Name three of the contaminants listed in this module section.
3. Complete the following sentence:

The term convexity is normally referred to the profile of a weld.

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 10

Guide 3

Carefully read pages 11 to 16 and answer the following questions:

1. True or False?

CSA W59, paragraph 5.9.5 and AWS D1.1-80, paragraph 9.25.1.5 state that undercut shall not be more than 1/32 inch (0.8 mm) deep when the weld is transverse to the primary stress in the part that is undercut.

2. From the following list, check off the categories of typical causes of weld concavity as listed in the module:

- a) Inadequate joint geometry
- b) Position of welding
- c) Process behaviour
- d) Change in essential variables
- e) Material type
- f) Incorrect operator manipulation

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 10

Guide 4

Carefully read pages 16 to 22 and answer the following questions:

1. True or False?

Careless chipping out of the back side of welds, so that the groove is displaced from the root of the weld, can lead to the misalignment of the weld.

2. From the following list, check off those which are listed in the module as Structural Faults in the weld zone:

- a) Convexity
- b) Overlap
- c) Hollow root
- d) Undercut
- e) Weld concavity
- f) Grouped porosity
- g) Slag lines
- h) Tungsten inclusions

3. Name three probable basic causes of porosity as categorized in the module.

4. True or False?

Slag left on the surface of tack welds may cause porosity.

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 10

Guide 5

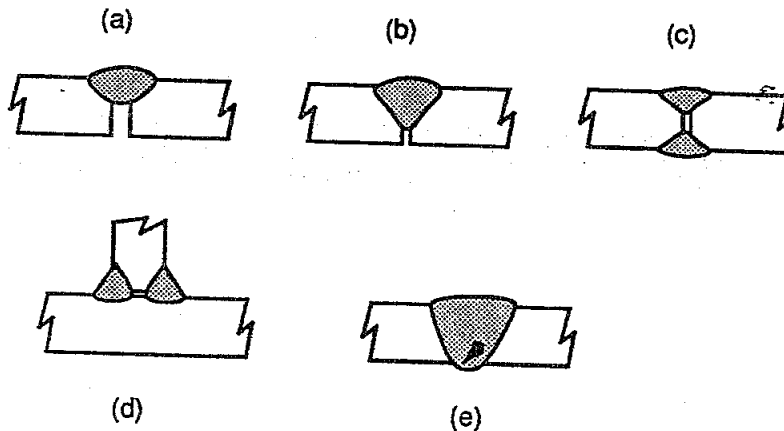
Carefully read pages 22 to 27 and answer the following questions:

1. True or False?

All the following are fusion faults in a complete penetration groove weld.

- a) Lack of sidewall fusion
- b) Incomplete penetration
- c) Lack of root fusion
- d) Underbead non-fusion/cold lap
- e) Lack of fusion insert
- f) Lack of fusion in fillet welds
- g) External undercut

2. Which of the following sketches does not depict incomplete penetration?



3. True or False?

Hydrogen induced cold cracks may occur in the weld metal or heat affected zone.

4. Complete the following sentence:

As the name implies, cold cracking forms at low temperatures, generally below° C.

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 10

Guide 6

Carefully read pages 27 to 31 and answer the following questions:

1. Name four causes of cracking as listed in the module.
2. Enter effects likely to occur with the welding conditions.

Welding Condition

Effects Likely to Occur

- a) Thick or rigid assemblies
- b) Hardenable material
- c) Cold weather
- d) Rust, oily or greasy joints

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 10

ANSWERS

Guide 1

1. (a) (d) (e)
2. (b)
3. 3/16

Guide 2

1. (a) (d) (e) (f)
2. Oil, paint, rust, mill, scale
3. Fillet

Guide 3

1. False
2. (a) (b) (c) (d) (e) (f)

Guide 4

1. True
2. (c), (f), (g), (h)
3. Moisture, chemistry and structure of parent material, surface impurities and contaminants, faulty electrodes, fluxes or shielding gases, slag, operator techniques.
4. True

Guide 5

1. False
2. (e)
3. True
4. 200

MODULE 10

ANSWERS continued

Guide 6

1.
 - 1) Hydrogen content of electrode
 - 2) Hydrogen impregnation of the parent material
 - 3) High sulphur content of the base material
 - 4) High carbon content of the base material
 - 5) High restraint on the joint
 - 6) Rapid cooling of hardenable and brittle material
 - 7) Welds too small for the size, rigidity and quenching effect of the parts joined.
 - 8) Poor joint fit up
 - 9) Unsuitable electrodes
 - 10) Secondary faults such as lack of penetration, porosity, elongated craters, etc.
2. Effects likely to occur:
 - a) Cracks in weld or fusion line
 - b) Cracks in either weld or base metal
 - c) Cracks in weld or base material
 - d) Porosity, inclusions and lack of fusion

MODULE 10

TEST

This test is designed to determine whether you are ready to attempt the formal examination.

Complete the ANSWER SHEET and compare the results with the TEST KEY. If you have a pass mark less than 70% you are advised to re-study the material.

1. Which of the following is a dimensional fault after welding?
 - (a) isolated gas holes
 - (b) slag lines
 - (c) incorrect Root openings
 - (d) none of the above
 - (e) insufficient throat

2. Tungsten inclusions are characteristics of the :
 - (a) carbon arc air metal removing method
 - (b) submerged arc welding method
 - (c) oxy-acetylene welding method
 - (d) inert atmosphere welding methods
 - (e) none of the above

3. Inadequate ductility in a weld is listed under:
 - (a) defective properties (weld metal and joint)
 - (b) hydrogen induced cold cracking
 - (c) dimensional faults and typical causes
 - (d) structural faults and typical causes
 - (e) none of the above

MODULE 10

TEST continued

4. In most cases, cold cracking occurs:
- (a) at 275°C
 - (b) at room temperature
 - (c) at 250°C
 - (d) at 0°C
 - (e) none of the above
5. Hydrogen impregnation of the parent metal is listed as a cause of :
- (a) irregular weld beads
 - (b) slag entrapment
 - (c) underbead lack of fusion
 - (d) cracking
 - (e) gas holes
6. The following term describes the melting away of the parent material during the welding process:
- (a) slag lines
 - (b) lack of fusion
 - (c) undercut
 - (d) incomplete penetration
 - (e) Hi-low
7. Which of the following is a structural weld fault?
- (a) slag inclusion
 - (b) incorrect fit-up
 - (c) incorrect joint design
 - (d) incorrect bevel angles
 - (e) insufficient throat

MODULE 10

TEST continued

8. Which of the following contributes to distortion after welding?
- (a) weld spatter
 - (b) inadequate control of weld pass sequencing
 - (c) tungsten inclusions
 - (d) slag lines
 - (e) surface porosity
9. Which of the following conditions create a quenched and brittle condition in alloy steel?
- (a) stray flashes
 - (b) spatter
 - (c) lack of fusion
 - (d) slag inclusions
 - (e) none of the above
10. Lamination in the weld bevels are a potential cause of:
- (a) incomplete penetration
 - (b) weld convexity
 - (c) weld concavity
 - (d) slag inclusions
 - (e) all of the above

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Answer Sheet - Module 10

Complete the "Answer Sheet" and compare the results with the "Test Key". If you have a pass mark less than 70%, you are advised to re-study the material.

Please circle only ONE letter corresponding to the answer you think is most correct.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

The answer key below is provided for your use in the event that you wish to retest yourself.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

Canadian Welding Bureau
Test Key - Module 10

Compare your answer sheet to this key.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e