# 2 Weld Discontinuities and Defects

## Objectives

Students will be able to:

- Distinguish between weld discontinuities and weld defects.
- Explain the four major types of porosity.
- Give examples of the most common discontinuities.
- Discuss the problems hydrogen causes during steel welding.

## Orienting Questions

- ✓ When inspecting a weld, what changes a discontinuity into a defect?
- ✓ What factors contribute to weldability?
- ✓ What are some sources of hydrogen contamination to weld?

## Keys for success

- ☐ Read and review required text along with this module
- ☐ Review key terms
- ☐ Do each and every activity in the module

## Helpful Tips

- ✓ You can select the **BLUE TERMS** to learn more.
- ✓ If needed, there are **CLOSED CAPTION** buttons **CC** on the YouTube videos that will enable you to read along while you watch. The Closed Caption buttons are located bottom right of the video screen.
- ✓ Anytime you see **EXPLORE** click on link or image to learn about the subject.
- ✓ Anytime you see me  click my image and let me read the text to you!
- ✓ When you see this book icon  it is alerting you to a reading assignment. Information will be provided by your instructor on the reading materials.
- ✓ Anytime you see this icon,  click on the image to watch a video about the module subject.

## INTRODUCTION

In module two we will discuss weld quality. When it comes to weld quality, there is no such thing as a perfect weld. Every weld has slight imperfections which are known as discontinuities. But, when that discontinuity exceeds the acceptable tolerance it then becomes a defect. We will also look into common causes and corrective actions for the many different discontinuities. We will also discuss the three discontinuities that are out of our control and due to imperfections of the base metal from the foundry or mill.

Read Chapter 23 of *Welding Principles and Applications* by Larry Jeffus, 7th edition.

## 2.1 WELDABILITY

Most of the time we think of weldability as the ease at which a material is welded. In reality it is much, much more. By definition, according to the American Welding Society (AWS), weldability is the capacity of material to be welded under the imposed fabrication conditions into a specific suitably designed structure and to perform satisfactorily in the intended service. Weldability is a total of the design, performance, and the ability to be welded. It is the sum of these different characteristics that leads to the weldability of the material. Figure 1 shows how the weldability of steel is affected by certain elements.

**Explore: What is Weldability?**

| *Element* | *Range for Satisfactory Weldability (%)* | *Level Requiring Special Care (%)* |
|---|---|---|
| *Carbon* | 0.06–0.25 | 0.35 |
| *Manganese* | 0.35–0.80 | 1.40 |
| *Silicon* | 0.10 max. | 0.30 |
| *Sulfur* | 0.035 max. | 0.050 |
| *Phosphorus* | 0.030 max. | 0.040 |

Figure 1. Weldability of steel (by Blodgett, civil-engg-world.blogspot.com, Public Domain)

### MODULE ACTIVITY 1

Complete the sentence.

1. ___________ (Structure, Weldability) is the capacity of material to be welded.

## 2.1.1 WELD DISCONTINUITIES

Each and every weld has a discontinuity of some type. Even though a weld may have a discontinuity, this does not mean that it is faulty or does not meet the acceptable standard**.** Discontinuities are simply imperfections in the structure of a weld. Even a weld done by machine will have discontinuities.

**Explore: Welding Discontinuities and Defects**

### 2.1.1.1 POROSITY

According to the American Welding Society (AWS), porosity is a cavity type discontinuity formed by gas entrapment during solidification of a weld. Most gases are contaminants to a weld. In many different ways we try to protect the weld puddle from foreign gases, such as the air we breathe. When these gases are allowed to make contact with the molten weld puddle, we will find the end result to be a discontinuity known as porosity. In other words, porosity is gas pockets that are trapped within the weld as it goes from a liquid state back to solid. Depending on the amount of porosity, it can lead into becoming a defect. The tolerance is according to the application and the applicable welding code to be followed. When we find porosity, we must fully remove it through mechanical means such as grinding. We must then address the root cause and ensure there is full protection from the atmosphere and replace the damaged weld material that was removed with new solid weld metal.

When stick welding or Shielded Metal Arc Welding (SMAW), porosity can be caused by damaged flux, bad technique, long arcing, or electrode condition such as wet electrodes holding humidity.

When (GMAW) Gas Metal Arc Welding (MIG) or (GTAW) Gas Tungsten Arc Welding (TIG), being that they are shielded by an external gas, we must find the root cause of why the protective gas is not reaching the weld puddle. Many times it may be as simple as we ran out of gas, failed to turn it on, have a damaged gas hose or an obstruction at the nozzle, or we are using bad technique in the way of nozzle or torch angle allowing the atmosphere to reach the weld puddle.

There are **four types** of porosity (see Figure 2) that need to be discussed.

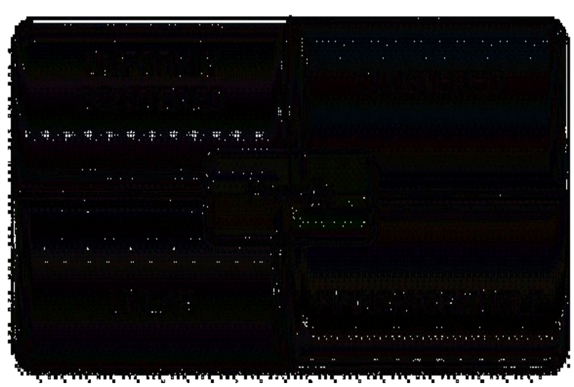


Figure 2: Types of Porosity (by Paul Phelps, CC BY 4.0)

**Uniformly Scattered Porosity** is most commonly a system failure and it will occur for the duration of the weld. Most times, this is not a technique issue but failure of some part of the system such as a lack of shielding at the weld. To correct this, we must track down the reason for that lack of shielding, whether it is replacing the gas or replacing the electrode with one in better condition. We must ensure shielding is provided at the molten weld puddle to protect it from the atmospheric gases.

**Clustered Porosity** is normally a matter of bad technique at the beginning of a weld. It is caused by long arcing as the arc is initiated. Continuous practice and mastering techniques in welding will correct clustered porosity.

**Linear Porosity** will be found in line with the joint that is being welded and is normally just bad work practices and not properly cleaning the base metal where the weld will take place. It can also be a matter of bad fit-up allowing atmosphere to reach the weld from the opposite side of the weld joint. Corrective action is to properly clean and fit-up all parts using proper work practices in preparation for the actual weld.

**Piping or Wormhole Porosity** is caused by gas that is trying to escape through the weld. This will create a hole within the weld. Piping/Wormhole porosity error looks like a hole made by a worm eating its way through an apple. The corrective action for this is to keep the molten puddle in the liquid state for a longer period of time. This allows for all gas, created from the welding process, to fully escape out of the weld into the slag. We can keep the molten weld puddle in the liquid state longer by increasing the heat input through turning up the voltage or amperage depending on the process, slowing our travel speed, decreasing wire speed so less energy is consumed in melting of the core wire, or shortening of the arc length thus generating more heat at the weld puddle allowing the gases to escape. See Figure 3 for actual examples.

**EXPLORE: Porosity**

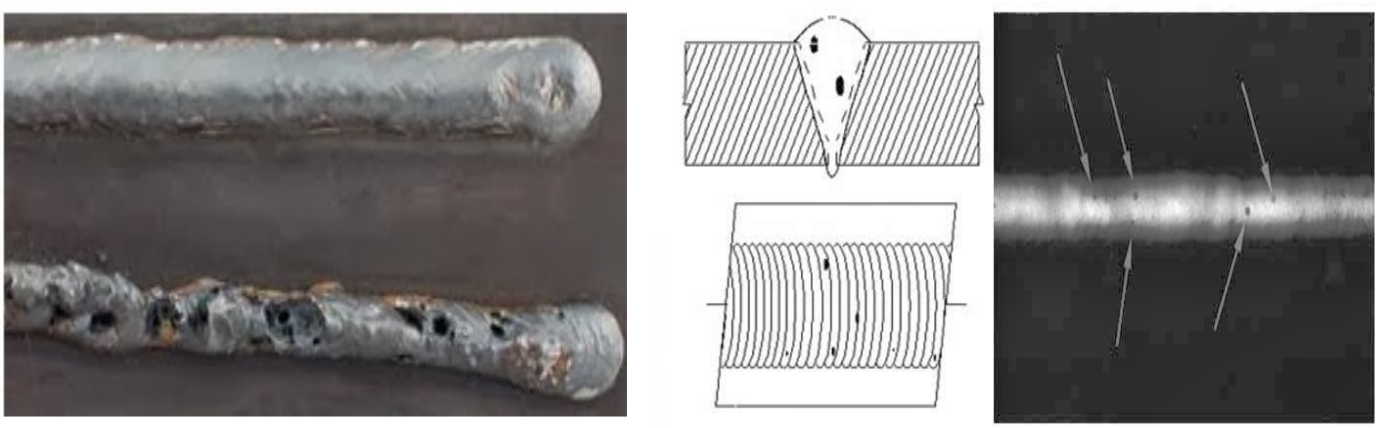


Figure 3. Examples of Porosity (by Shikh Ahmad Hanif / Amir Azli Mohd Al-Kharid, Public Domain)

### 2.1.1.2 INCLUSIONS

According to the AWS, **Inclusions** are entrapped foreign solid material such as slag flux tungsten or oxides. Inclusions are a problem because they create voids within the weld which undermine the through thickness.

Depending on whether you are the welder or the engineer, the through thickness may be referred to as actual throat (welder), effective throat, or theoretical throat (engineer). As welders on the job, we find our welds are sized by leg length for fillet welds (Figure4) or by throat for groove welds (Figure 5). The importance in understanding these terms is to understand how one inclusion undermines the effective part of the weld. When an inclusion is present the void created by the inclusion removes a certain amount of weld metal. With this removal there is less material present to adequately support the weld as it was designed. The shape of that inclusion most times will have sharp edges or points which create what are known as stress risers, which are points that are likely for stress to be focused and lead to cracking. We can clearly see inclusions in nondestructive techniques such as radiographic a.k.a. x-rays. Many times we can produce inclusions and not be aware of them as they are trapped below the surface. Therefore it is standard practice to do routine inspections using different techniques to look below the surface and ensure the absence of these inclusions. When inclusions are present they must be removed mechanically or thermally and replaced with new sound material.

The most common causes of inclusions when stick welding or Shielded Metal Arc Welding (SMAW) is bad technique regarding electrode angle, arc length being too long, improper or incomplete cleaning of a completed weld, or weld progression. The best corrective actions is a review of proper technique and practice.

With short arc or (GMAW) Gas Metal Arc Welding (MIG) welding, inclusions are not as common because it does not create a slag on the surface of the weld. Related processes, such as FCAW a.k.a. **Flux Cored Arc Welding**, can be very prone to inclusions if improper technique is used. When using FCAW, it is best practice to use a dragging technique pulling the puddle of molten weld metal along in order for new metal to be deposited on the forward edge of the weld puddle. By doing this, we are less likely to push slag into the completed weld. Gun angle should be near vertical with only 10° or so of angle in the direction of travel, so that all heat of the welding process is pushed directly into the center of the joint.

(GTAW) Gas Tungsten Arc Welding (TIG) welding is a very clean process but can create inclusions of tungsten if lack of control or bad techniques is employed. If, while welding, the weld puddle becomes contaminated by the tungsten being dipped into the molten weld puddle, a portion of the tungsten will be left behind in the weld. Tungsten is a very hard, heat resistant material that will not be consumed into the weld but creates a void again undermining the strength of that weld. Tungsten inclusions are very clearly evident in an x-ray (Figure 6) to the welding inspector. Therefore the welder must be disciplined and ensure that any and all contamination of tungsten into the weld puddle is fully removed mechanically and that sound metal is put back in its place. Many times we will not see signs of any tungsten, so it is in the welder's hands to be disciplined to take the correct steps and corrective actions to remove it. Repair of contaminated sections is very costly.

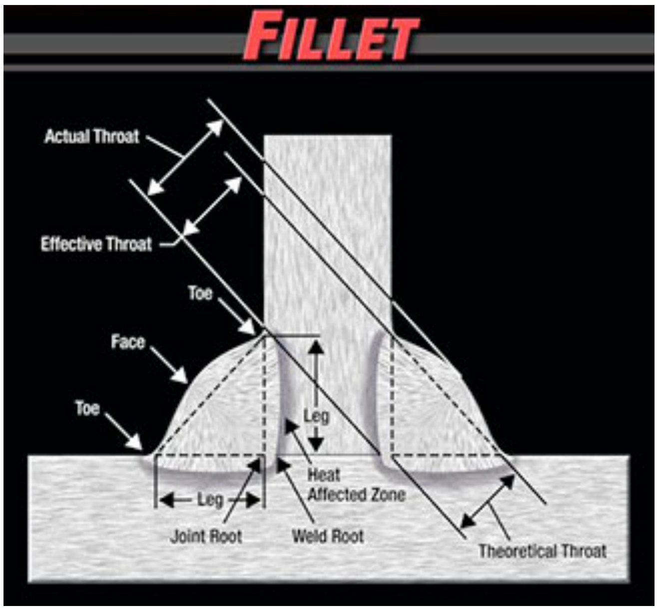



Figure 4: Parts of a Fillet Weld (by Lincoln Electric, Public Domain)

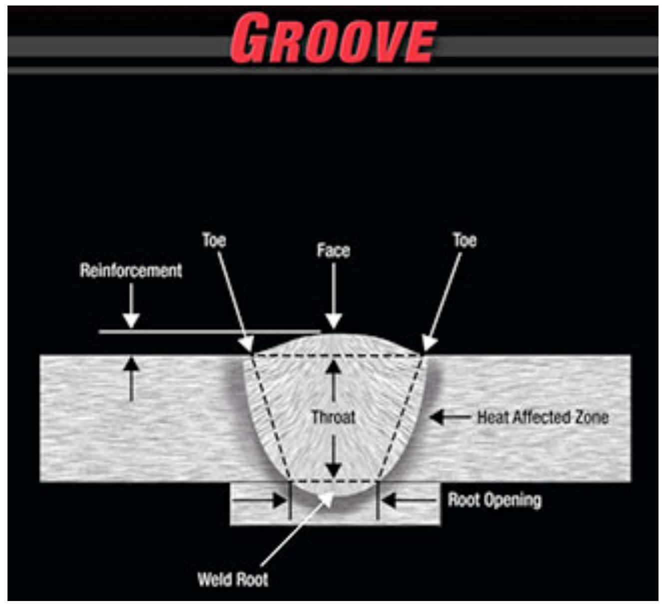



Figure 5: Parts of a Groove Weld (by Lincoln Electric, Public Domain)

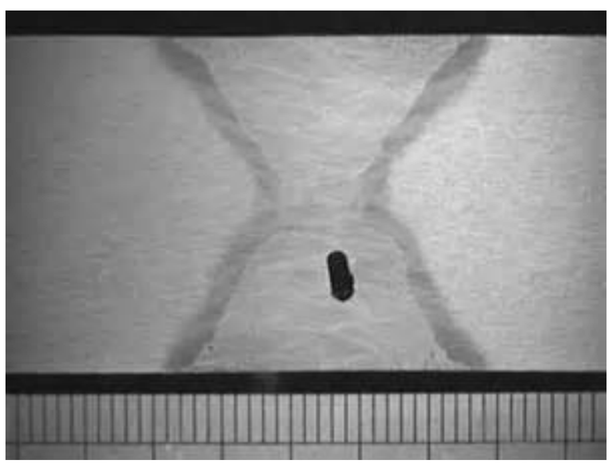


Figure 6. Cross section of a welding inclusion (by Lucas W., Marcello Consonni, Chen Fun Wee and Charles Schneider, Courtesy of TWI Ltd.)

## MODULE ACTIVITY 2

Choose the correct answer.

1) Discontinuities are imperfections in the weld. T/F
2) There are six types of porosity. T/F
3) Inclusions are trapped foreign solid material in a weld that cause a void. T/F
4) The most common reason for an inclusion in SMAW is poor technique. T/F

## 2.1.1.3 INADEQUATE JOINT PENETRATION

**Inadequate Joint Penetration** (Figure 7) is when the weld does not penetrate deep enough into the weld joint to provide adequate fusing through the metal. Depending on the weld joint, fillet weld (Figure 4) versus groove weld (Figure 5), the weld did not penetrate fully and leaves an un-fused edge as you can see in the graphic below. The un-fused edges create stress risers that can lead to cracks and failure of the joint. Each and every weld has an intended through thickness of weld metal which requires a certain amount of fusion into the joint. If we fail to reach that level we are undermining the strength and this can lead to failure points.

Common causes of inadequate joint penetrations are welding at too low of an amperage or voltage for the material that you were working with, bad technique by misdirecting the heat and intensity of the welding arc, improper joint design, or improper fit up.

Corrective action can be as simple as following correct procedures and welding at adequate amperage or voltage setting for the material and thickness that we will be welding. Joint design typically is beyond the daily welder's ability to dictate. This is normally controlled and specified by the welding engineer on staff or the design engineer. As welders, when we have an inability to generate the penetration levels required, we must then confer with the engineers to look at alternatives for change in design. This type of communication can lead to an improved product and ensures the quality of the finished product.

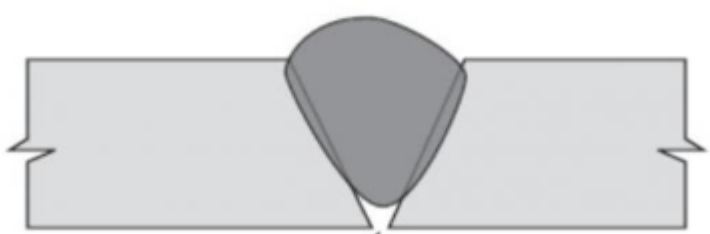


Figure 7. Diagram of Inadequate Joint Penetration (by unknown, Public Domain)

## 2.1.1.4 INCOMPLETE FUSION

Incomplete Fusion is the lack of merging between the molten filler metal and the base metal or the previous weld (Figure 8). We can see incomplete fusion where the weld metal meets the sidewall in a fillet weld or groove weld. Many times we will see it where the new weld does not completely fuse into the previous weld, creating a weak spot where the two join.

Common causes for incomplete fusion can be as simple as inadequate agitation which is lack of manipulation of the puddle, wrong welding process needed to generate adequate heat for penetration, improper preparation, or improper joint design.

Corrective action is to ensure we are welding at a voltage or amperage level adequate to the thickness of base metal and type. It is critical to use proper technique and focus heat and intensity of the welding arc to ensure penetration into the base metal or previous weld. Proper cleaning of materials to remove oxides or contaminants will ensure the weld metal can penetrate into the base by removing obstacles in its path such as materials that will inhibit its ability to penetrate. Most times the only way to properly identify lack of fusion is to do routine destructive testing. Most critical welds on a job should have physical procedures outlining setup, preparation, and technique that welders must follow.  These procedures are established for consistency and quality of work.

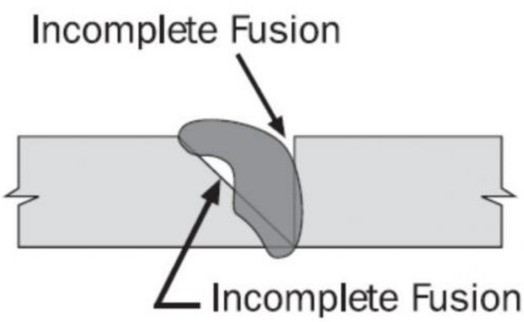



Figure 8. Diagram of Incomplete Fusion (by unknown, Public Domain)

### MODULE ACTIVITY 3

Complete the following sentences.

1. The lack of merging between the molten filler metal and the base metal is called
    a. Porosity
    b. Inclusion
    c. Inadequate Joint Penetration
    d. Incomplete Fusion

2. Inadequate Joint Penetration is caused by _________ (inadequate amperage, moisture)

## 2.1.1.5 ARC STRIKES

Arc Strikes are where the electrical arc is allowed to pass across the base metal in an area away from the weld zone without any weld metal being deposited (Figure 9). This results in burn marks on the surface of the base metal which creates a hotspot that in turn hardens and will form microscopic cracks on the surface. Cracks in general will spread so cracks initiated due to an arc strike are completely unacceptable. These cracks are easily detected in an acid etch or die penetrant test. In the past, welders would grind polish to cover up evidence of an arc strike. Unfortunately, once an arc strike is in place, the damaged material has to be replaced, not just covered up.

Corrective action is through the discipline of the welder to ensure that he only strikes or initiates the arc in the weld zone. Through precise control, discipline, and consistency, the welder can ensure that they do not create arc strikes.

Example of an Arc Strike

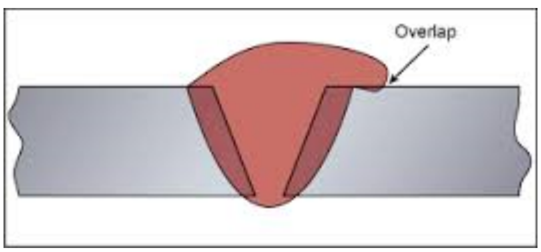
Figure 9. Picture of Arc Strikes ( unknown, Public Domain)

## 2.1.1.6 OVERLAP

Overlap, also known as cold lap, takes place when the weld becomes too large for the base metal to accept and rolls out a position (Figures 10 and 11). As it rolls over on top of itself, it creates a cold edge that does not fuse into the material below. Cold lap is very common in the horizontal position as gravity is grabbing at the molten weld puddle and pulling it over on top of itself. It is possible to see overlap take place in fillet or groove welds. The problem with overlap is the fact that when it does roll over on itself, the unfused edge creates a void within the weld where the weld is not completely merged into the base metal or the previous weld. This can severely cut the effective amount of weld metal that truly reinforces the weld joint.

Common causes of an overlap are too high amperage or voltage generating more heat than the base metal can accept therefore allowing the weld to sag over on itself. Also, we can see this as a result of bad technique when the heat of welding is misdirected and again allowing the weld to roll over on itself out of control.

Corrective action is not as simple as welding back over it and expecting to fuse into and through the metal. Once an overlap has occurred, it must be fully removed and replaced with a new weld. If you choose to put a new weld over the top of the overlap, the rollover cold edge must be removed prior to the new weld being put on top otherwise it will not penetrate through the cold edge preventing joining it all into one solid piece.



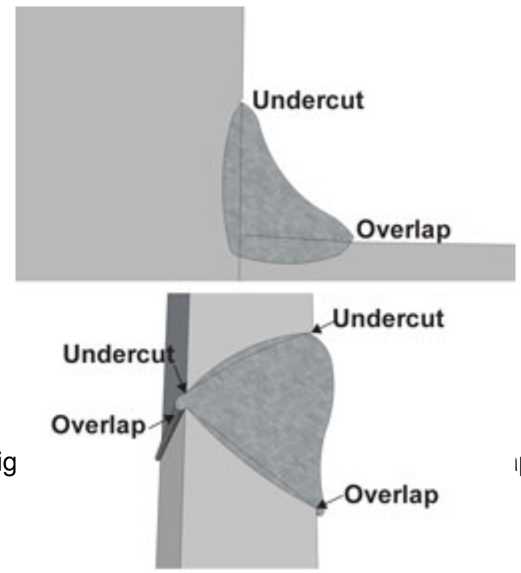




Fig [illegible] ps

## MODULE ACTIVITY 4

Choose the correct answer.

1. This welding flaw causes burn marks and microscopic cracks on the material surface.
    a. Overlap
    b. Inclusion
    c. Arc Strike
    d. Undercut

2. This welding flaw is also known as a cold lap.
    a. Inclusion
    b. Arc Strike
    c. Overlap
    d. Porosity

## 2.1.1.7 UNDERCUT

**Undercut** is a groove along the edge of a weld resulting from excessive heat allowing the welding arc to melt away the base metal faster than it is being replaced by the new weld metal (Figure 11 and 12). The severity of the depth and/or length of an undercut determines whether it would be a defect or acceptable due to being within tolerance. Each welding code specifies how much undercut is acceptable, typically not deeper than one 32nd of an inch and no more than a couple of inches of a linear foot. Anything over this tolerance therefore becomes a defect and unacceptable. Specific tolerance criteria is detailed in the applicable code book.

One common cause of undercut is generating too much heat on one side of the weld joint due to improper rod, torch, or gun angle. Undercut can also be a result of excessive voltage or amperage, long arcing, excessive travel speed, or puddle manipulation technique or pattern. If it is a gas shielded process, such as short arc MIG welding, going to a gas that generates less heat may generate a less stable arc resulting in undercut.

Corrective action depends on proper setup, parameters, and technique. Weld procedures specify proper setup and parameters but technique is in the hands of the welder. The welder must ensure if using a manipulation technique to move a large puddle, they must make sure not to travel beyond the puddle allowing the welding arc to undercut at the edge. Other causes of undercut such as rod, torch, or gun angle, long arcing and travel speed depend on the welder's ability and technique. So as you can see, if the welder is following procedure but they continue to see undercut, it may mean the welder needs additional practice in that technique to produce welds of proper quality without undercut.

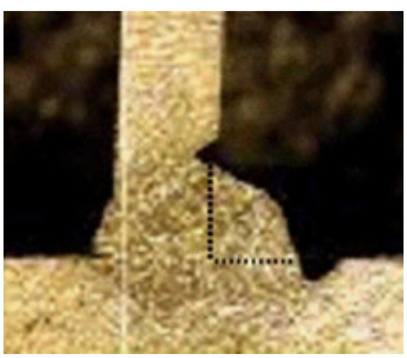


Figure 12. Picture of an Undercut
(by Ed Craig and Richard Green, Public Domain)

## 2.1.1.8 CRACKS

Any type of crack is unacceptable in any weld. Cracks come from many different causes. They form in different locations and have the ability to spread in different directions. Figure 13 shows a number of different types of cracks, where they initiate, and how they can spread. Causes of cracks vary depending on type of material, process, and technique.

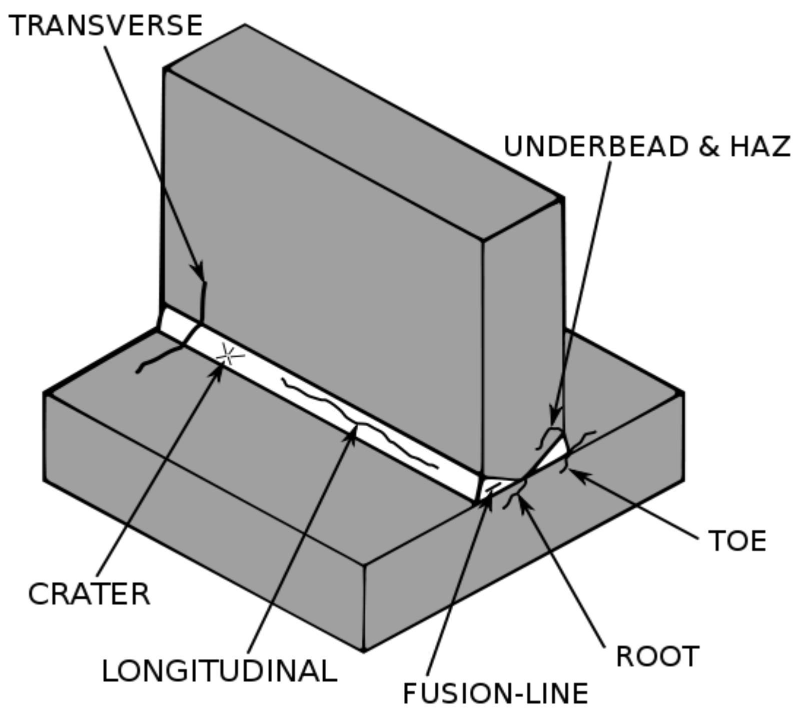



Figure 13. Figure of Different Types of Cracks (by Wizard191, Public Domain)

- *CRATER CRACKS*

Crater Cracks, as you can imagine by the name, form at the crater or the termination of the weld (Figure 14). When the crater does not fill up to the same height as the weld, giving adequate reinforcement, the weld risks forming a crater crack. All welded materials will shrink as they cool. The amount of shrinkage varies depending on the material. So when the material is lacking at the termination of the weld in the crater, there is not enough material to absorb the stresses as it shrinks. When this happens all of the stress is forced to the center but the weld cannot withstand the forces so a crack will form in the center of the crater. The crater crack then has the opportunity to run down the length of weld causing the weld joint to fail.

Corrective actions or preventive actions can be as simple as using the correct owl oil filler metal, which will freeze and shrink at a level where the material can handle that kind of stress. Also we can vary technique and give a slight pause at the termination of the weld to allow the crater to fill up to the same height as the weld before terminating the arc. Some GMAW gas metal arc welding equipment will also have a crater fill function which in turn adds additional metal into the weld puddle prior to terminating the arc. If available, it is desirable to use that function to limit the opportunities for crater cracks.

Figure 14. Picture of a Crater Crack (by Paul Cameron, Public Domain)

- *HOT CRACKS*

Read Chapter 25 of *Welding Principles and Applications* by Larry Jeffus, 7th edition.

**Hot Cracks** are visible while the weld is still hot and normally will form towards the center of the weld (Figure 15). Hot cracks can be caused by a poor bond or fusion between the weld metal in the base which results when the crystal structures do not fully bond together. As the weld cools and shrinks it will rupture. Many times we will find an undersized weld or improperly shaped weld to be the culprit because there is not enough material to absorb the stresses from the shrinking.

Corrective action is to make sure that the welding alloy matches and has compatible chemistry with the base metal so that they properly fuse and then will resist stress formations. In addition to the correct welding alloy, weld size and shape are critical in preventing hot cracks. Welders need to refer to the applicable code information where there are graphics and specification showing the proper contour and shape of a finished weld. The ideal weld is fairly flat and will rarely be concave, as a concave weld can be susceptible to cracking due to lack of material present to absorb the stresses as it shrinks.

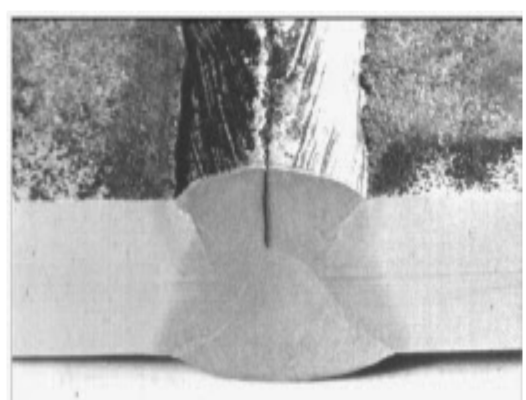


Figure 15. Picture of a Hot Crack (by Shikh Ahmad Hanif / Amir Azli Mohd Al-Kharid, Public Domain)

- *COLD CRACKS*

Cold Cracks are a result of hydrogen being introduced into the molten weld puddle and then spreading into the heat affected zone on the edges of the weld. Many times a cold crack may be referred to as hydrogen induced cracking or delayed cracking. We find this to be a very common crack in certain types of materials. For materials that are susceptible to this type of cracking, welding code requires them to be inspected up to 72 hours after they were produced. If these susceptible materials are going to crack they typically will do so by the 72 hour mark.

Corrective action and/or preventive action is to limit the chances of hydrogen entering the weld zone. Hydrogen most commonly enters the weld zone in the form of humidity or water. Therefore it is very important to monitor work conditions. The dew point must be monitored to make sure that water or humidity is not forming on the electrode and/or base metal prior to the welding made. In the event it has, actions will be needed to try and remove moisture in preparation for the weld. If humidity is present on the base metal, it may mean preheating the material to remove water and or humidity prior to the weld. If humidity is present on the electrodes, allowing them to be dried may be sufficient. Some electrodes made from spooled material may require they be discarded due to being contaminated. Some specialty low hydrogen electrodes, like 7018 stick welding electrodes have fluxes that are designed to fight the formation of hydrogen. The 7018 electrode has one drawback, it is susceptible to absorbing moisture which has the hydrogen we are trying to guard against. Therefore, we must bake the electrode in an oven designed to keep the humidity baked out of the electric flux. (AWS) American welding society D1 .1 welding code for structural steel is very specific in the handling of 7018 or low hydrogen electrodes to ensure they perform adequately. The structural steel code specifies that low hydrogen electrodes are to be purchased in a hermetically sealed container and once opened, after four hours of being in the open air, enter an oven and be baked at a minimum of 250°F. These electrodes can only be re-baked once. If they become wet at any time they are to be discarded and not used.

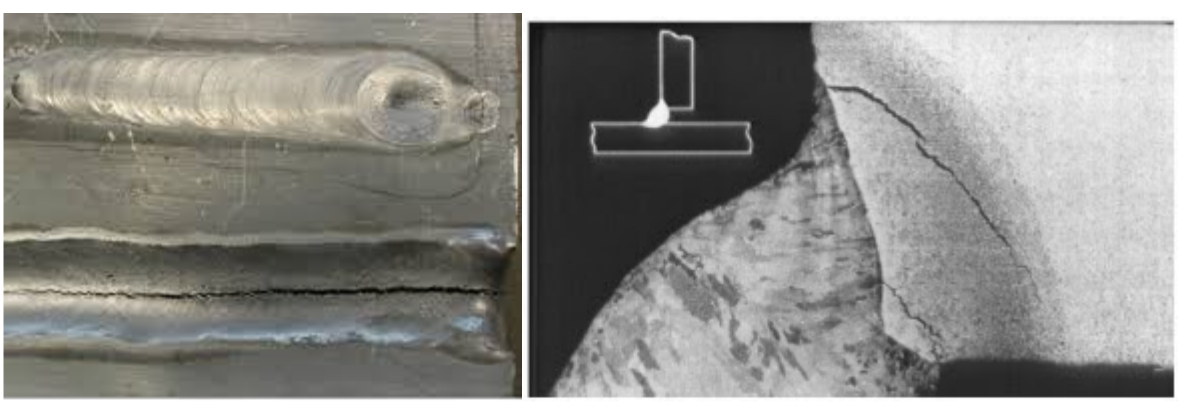


Figure 16. Pictures of Cold Cracks (by Shikh Ahmad Hanif / Amir Azli Mohd Al-Kharid, Public Domain)

- *CARBIDE PRECIPITATION*

**Carbide Precipitation** is a type of cracking that takes place in stainless steels (Figure 17). Stainless steels are known for their resistance to corrosion. This resistance to corrosion is due to the presence of chrome nickel in the base metal. When working with stainless steels, we must be very mindful of the heat input into the base metal as adverse effects can be seen when overheated. Overheating can be very evident in the colors of the base metal. When welding on stainless steel, we are trying to maintain a nice golden brown color in the weld or a very light rainbow color spectrum. When we start seeing darker colors such as blues, purples, and blacks, we risk overheating materials and creating this carbide precipitation. In its simplest sense, when we overheat the material we weld, we force the chromium away from the heat affected zone and push it out into the base metal. When this takes place, the chromium is not in the heat affected zone, therefore the heat affected zone loses the corrosion resistance characteristics and can corrode rapidly causing the area next to the weld to oxidize, rust, and fail. The chromium, as it pushes out into the base metal, can cause the formation of carbides which are very hard materials.

Corrective action is to monitor heat input into the base metal to make sure we do not enter the danger zone. If we reach 800°F it is common to start seeing those dark blues, purples, and blacks. It is also a common practice to use a low carbon electrode to limit the chances of forming carbides.

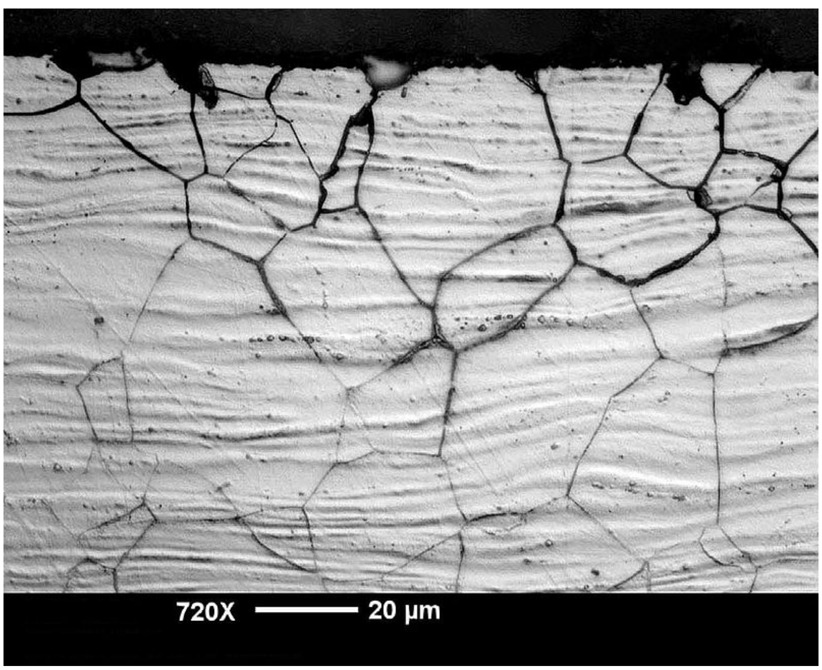



Figure 17. Picture of Carbide Precipitation in Stainless Steel
(by Antkyr, CC BY-SA 3.0)

## MODULE ACTIVITY 5

Choose the correct answer.

1. Carbide Precipitation is a type of cracking in stainless steels. T/F
2. Hot Cracks form on the edges of the weld. T/F
3. Cold Cracks result from hydrogen being introduced into the weld. T/F
4. Metal cooling and shrinking at the termination of the weld can result in a Crater Crack. T/F
5. A severe Undercut can be a defect. T/F
6. Not all cracks in a weld are a problem to be corrected. T/F

### 2.1.1.9 UNDER FILL

Under fill can take place in a group weld or a fillet weld. It is simply the lack of weld metal in that particular weld joint (Figures 18 and 19). This weakens the weld due to the lack of material. Corrective action can be as simple as making the properly sized and shaped weld, and making sure not to miss a weld in a multi-pass weld joint. It seems simple but slowing down our travel speed be all it takes to make sure the weld profile or shape is correct and properly reinforces the joint as it was designed.

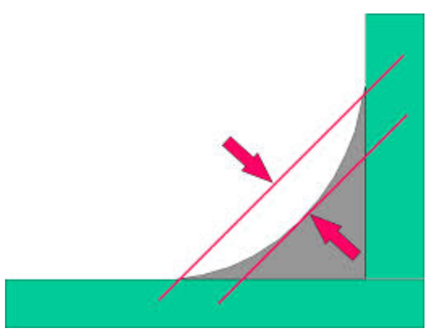


Figure 18. Representation of Under fill (by Gelson Luz, Public Domain)

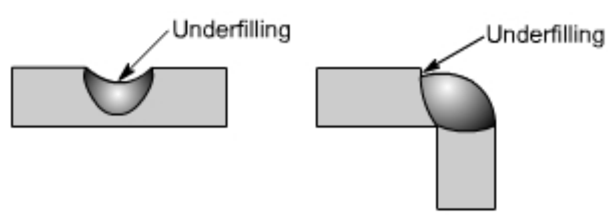



Figure 19. More Examples of Under Fill (by Prof. S.R. Gupta, Public Domain)

## 2.1.1.10 LAMINATIONS

Laminations are where nonmetallic materials form towards the center creating a void within that material (Figure 20). They are common in thick materials. Metal comes from the ground therefore it comes out with additional elements, rock, and dirt that may not be fully refined out. Laminations are out of the welders control but once identified, the faulty material must be removed from production. It is very critical for the materials to be taken out of production because once heat is introduced at that weld location it will change form and create our next discontinuity. More than likely if there is one bad piece of material there will be more. It may not all be at your location. Steels, as they are produced, are tracked and identified by what are known as the heat numbers. These are the numbers that you may see printed on the surface of that plate. This way the mill can identify when it was produced and the conditions at the time of production. Everything was recorded for that day when it was made. As that batch is sold and distributed, we can track where it went. It could be detrimental to the safety of all of us if defective steel is not tracked and discarded when determined to be flawed.

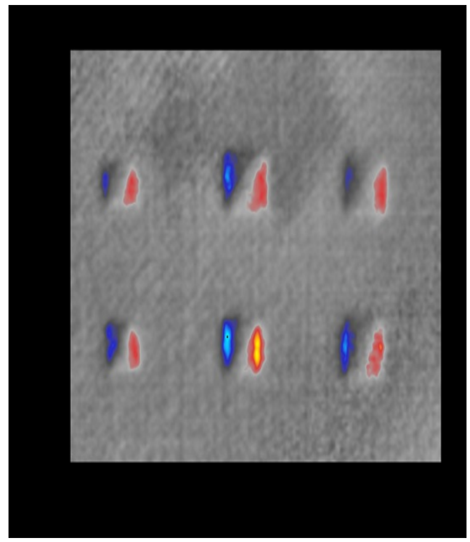


Figure 20. Picture of Lamination (by Ozzie Griffin, Public Domain)

## 2.1.1.11 DELAMINATIONS

Delaminations began as laminations but when it was heated through welding or was thermally being cut, it puckered and formed a delamination (Figure 21). The pucker is the lamination as it pushes apart from itself. The corrective action is the same as a lamination removal of the material, and reporting of the material so that the faulty material can be captured regardless of where it went.


Figure 21. Picture of Delamination (by Shearo, CC BY-SA 3.0)

## 2.1.1.12 LAMELLAR TEARS

Lamellar Tears are cracks that are parallel and below the surface of the plate (Figure 22). This discontinuity is a result of a thin layer of nonmetallic materials that form just below the surface of the plate and this formation is not ductile. Lamellar tears will form stair step- like cracks under stress caused by welding or bending. When identified, lamellar tears should be treated like laminations and delaminations and be removed from production. Changing joint design can prevent the formation of the stresses that caused this type of cracking separation.

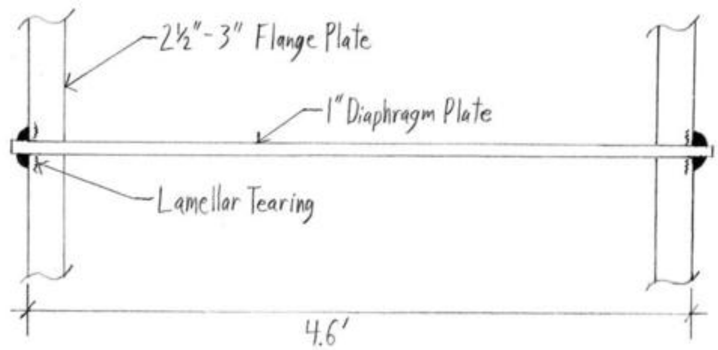



Figure 22. Lamellar Tearing Sketch
(by Seth M. Moyer, CC BY-SA 3.0)

## MODULE ACTIVITY 6

**Match the key terms with the appropriate definition or statement below.**

A. Arc Strike
B. Clustered Porosity
C. Cold Cracks
D. Crater Cracks
E. Delamination
F. Flux Cored Arc Welding
G. Gas Metal Arc Welding
H. Gas Tungsten Arc Welding
I. Hot Cracks
J. Inadequate Joint Penetration
K. Lamellar Tear
L. Lamination
M. Linear Porosity
N. Overlap
O. Shielded Metal Arc Welding
P. Under fill
Q. Uniformly Scattered Porosity

1. Forms at the termination of the weld when the crater does not fill up to the same height as the weld giving adequate reinforcement. ______
2. Cracks parallel and below the surface of the plate. ______
3. Where the electrical arc is allowed to pass across the base metal in an area away from the weld zone without any weld metal being deposited. ______
4. Where nonmetallic materials form towards the center creating a void within that material. ______
5. Found in line with the joint that is being welded and is normally just bad work practices, not properly cleaning the base metal or be a matter of bad fit-up. ______
6. Short arc welding. ______

7. The lack of weld metal in that particular weld joint. ______
8. Stick welding. ______
9. Takes place when the weld becomes too large for the base metal to accept and rolls out a position. ______
10. Where nonmetallic materials form towards the center creating a void and then a pucker in the metal being welded. ______
11. Porosity that is not a technique issue but failure of some part of the system. ______
12. When the weld does not penetrate deep enough into the weld joint to provide adequate fusing through metal. ______
13. TIG welding. ______
14. A matter of bad technique at the beginning of a weld caused by long arcing as the arc is initiated. ______
15. The result of hydrogen being introduced into the molten weld puddle and then spreading into the heat affected zone on edges of the weld. ______
16. Type of welding where it is best practice to use a dragging technique pulling the puddle of molten weld metal along in order for new metal to be deposited on the forward edge of the weld puddle. ______
17. Visible while the weld is still hot and normally will form towards the center of the weld. ______

## 2.2 WELD DEFECTS

Defects are when the discontinuity or group of discontinuities exceeds the tolerance of the applicable code. Once it exceeds this tolerance it then transfers from a discontinuity into a defect. There are some defects that are considered automatic defects due to what they may lead to. For example, all cracks are considered unacceptable because it is a proven fact that they will spread over time and become larger and lead to possible failure of the affected component.

### MODULE ACTIVITY 7

**True/False**: Indicate whether the statement is true or false.

1. A discontinuity does not exceed the tolerance of the applicable code. T/F
2. The capacity of material to be welded under the imposed fabrication conditions into a specific suitably designed structure and to perform satisfactorily in the intended service is called weldability. T/F
3. Defects are slight imperfections in the structure of a weld. T/F

## MODULE 2 VIDEO

Click on the video icon to watch a video demonstrating how to "Detect Welding Defects in Real Time."

# MAJOR CONCEPTS

## KEY CONCEPTS

- All welds have discontinuities. Discontinuities are flaws in a weld, not all will cause a weld fail. But some are completely unacceptable and will be considered a defect once identified that they exist.
- Defects are specified by the code. The code gives us the tolerance for the discontinuities and sets the limits of how much is allowed before they are considered effective.
- There are some discontinuities that are out of our control and created or formed within the material when they were produced at the mill.

## KEY TERMS

American Welding Society
Arc Strike
Carbide Precipitation
Clustered Porosity
Cold Cracks
Crater Cracks
Defects
Delamination
Discontinuities
Flux Cored Arc Welding
Gas Metal Arc Welding
Gas Tungsten Arc Welding
Hot Cracks
Inadequate Joint Penetration
Inclusion
Incomplete Fusion
Lamellar Tear
Lamination
Linear Porosity
Overlap
Piping or Wormhole Porosity
Porosity
Shielded Metal Arc Welding
Undercut
Under fill
Uniformly Scattered Porosity
Weldability

# ASSESSMENT

## MODULE REINFORCEMENT

**True/False**: Indicate whether the statement is true or false.

____ 1. All welds have discontinuities and flaws, but they are not necessarily defects.

____ 2. Uniformly scattered porosity is most frequently caused by contamination at the root.

____ 3. Arc strikes can be removed by grinding.

____ 4. Porosity causes most of the effects of oxygen.

____ 5. A high sulfur content is most often responsible for cold cracking in steel.

**Multiple Choice**: Identify the choice that best completes the statement or answers the question.

____ 1. A ____ is an interruption in the typical structure of the weld, whereas a ____ is a flaw which renders the part unable to meet minimum acceptance standards.

a) tolerance, flaw
b) tolerance, discontinuity
c) failure, discontinuity
d) discontinuity, defect

____ 2. Each code gives the ____ that changes a discontinuity to a defect.

a) procedure
b) correction
c) tolerance
d) flaw

____ 3. ____ result(s) when gas that was dissolved in the molten weld pool forms bubbles that are trapped as the metal cools to become solid.

a) Porosity
b) Inclusions
c) Incomplete fusion
d) Laminations

____ 4. ____ appear(s) in either spherical or cylindrical form.

a) Porosity
b) Inclusions
c) Incomplete fusion
d) Laminations

____ 5. ____ is/are nonmetallic materials trapped in the weld metal, between weld beads, or between the weld and the base metal.

a) Porosity
b) Inclusions
c) Incomplete fusion
d) Laminations

____ 6. ____ is/are the lack of coalescence between the molten filler metal and previously deposited filler metal and/or the base metal.

a) Porosity
b) Inclusions
c) Incomplete fusion
d) Laminations

____ 7. ____ is a groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.

a) Arc strike
b) Crater crack
c) Cold lap
d) Undercut

____ 8. ____ is the property that allows a metal to withstand forces, sudden shock, or bends without fracturing.

a) Hardness
b) Brittleness
c) Toughness
d) Strength

____ 9. ____ is caused by gas that is trying to escape through the weld most often caused by contamination at the root.

a) Linear porosity
b) Uniformly scattered porosity
c) Wormhole porosity
d) Clustered porosity

____ 10. ____ is a type of cracking that takes place in stainless steels.

a) Hot crack
b) Carbide precipitation
c) Crater crack
d) Cold crack

**Completion**: Complete each statement.

1. ____________________ inclusions can resemble porosity, but, unlike porosity, they are generally not spherical.

2. Arc strikes will always appear when an acid ____________________ is used.

**Short Answer**: Give a brief answer for each question below.

1. What causes crater cracks and how can they be prevented?

2. Explain the causes for lamellar tears and how they can be prevented.

## DISCUSSION PROMPTS

Which discontinuities are considered automatic defects and unacceptable?

What are four types of porosity's and root causes for them?

# ANSWER KEY TO MODULE ACTIVITIES

## ACTIVITY 1

1. Weldability

## ACTIVITY 2

1. T
2. F
3. T
4. T

## ACTIVITY 3

1. D
2. inadequate amperage

## ACTIVITY 4

1. c
2. c

## ACTIVITY 5

1. T
2. F
3. T
4. T
5. T
6. F

## ACTIVITY 6

1. D
2. K
3. A
4. L
5. M
6. G

7. P
8. O
9. N
10. E
11. Q
12. J
13. H
14. B
15. C
16. F
17. I

## ACTIVITY 7

1. T
2. T
3. F

## ANSWERS TO ASSESSMENT QUESTIONS

**TRUE/FALSE** (textbook page reference)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | ANS: | T | PTS: | 1 | REF: | 568 |
| 2. | ANS: | F | PTS: | 1 | REF: | 569 |
| 3. | ANS: | F | PTS: | 1 | REF: | 572 |
| 4. | ANS: | F | PTS: | 1 | REF: | 661 |
| 5. | ANS: | F | PTS: | 1 | REF: | 662 |

## MULTIPLE CHOICE

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | ANS: | D | PTS: | 1 | REF: | 568 |
| 2. | ANS: | C | PTS: | 1 | REF: | 568 |
| 3. | ANS: | A | PTS: | 1 | REF: | 568 |
| 4. | ANS: | A | PTS: | 1 | REF: | 568-569 |
| 5. | ANS: | B | PTS: | 1 | REF: | 570 |
| 6. | ANS: | C | PTS: | 1 | REF: | 571 |
| 7. | ANS: | D | PTS: | 1 | REF: | 573 |
| 8. | ANS: | C | PTS: | 1 | REF: | 643 |
| 9. | ANS: | C | PTS: | 1 | REF: | 569 |
| 10. | ANS: | B | PTS: | 1 | REF: | 663 |

## COMPLETION

1. ANS: Scattered

PTS: 1 REF: 570

2. ANS: etch

PTS: 1 REF: 572

## SHORT ANSWER

1. ANS: Crater cracks are the tiny cracks that develop in the weld craters as the weld pool shrinks and solidifies. Materials with a low melting temperature are rejected toward the crater center while freezing. Since these materials are the last to freeze, they are pulled apart or separated, as a result of the weld metal's shrinking as it cools. The high shrinkage stresses aggravate crack formation. Crater cracks can be minimized, if not prevented, by not interrupting the arc quickly at the end of a weld. This allows the arc to lengthen, the current to drop gradually, and the crater to fill and cool more slowly. Some GMAW equipment has a crater filling control that automatically and gradually reduces the wire feed speed at the end of a weld. For all other welding processes

the most effective way of preventing crater cracking is to slightly pull the weld back allowing it to pool up on the weld bead before breaking the arc.

PTS: 1 REF: 573

2. ANS: Lamellar tears appear as cracks parallel to and under the steel surface. In general, they are not in the heat-affected zone, and they have a step like configuration. They result from the thin layers of nonmetallic inclusions that lie beneath the plate surface and have very poor ductility. Although barely noticeable, these inclusions separate when severely stressed, producing laminated cracks. These cracks are evident if the plate edges are exposed. A solution to the problem is to redesign the joints in order to impose the lowest possible strain throughout the plate thickness. This can be accomplished by making smaller welds so that each subsequent weld pass heat treats the previous pass to reduce the total stress in the finished weld. The joint design can be changed to reduce the stress on the through thickness of the plate.

PTS: 1 REF: 574

## ATTRIBUTION TABLE

| Author/s | Title | Source | License |
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