5 Testing

Objectives

Students will be able to:

- Explain the importance of welding codes.
- List the steps in the typical process to become qualified to weld specific welding projects.
- Describe the eight variables that require recertification if changed in a welding project.
- Identify the required welding documents
- Compare and contrast destructive and nondestructive testing.
- List and define common destructive and nondestructive testing techniques.

Orienting Questions

- ✓ Why are welding codes important?
- ✓ What does a welder have to do to get a welding project certified?
- ✓ What documents are used for each weldment?
- ✓ What are the variables that require recertification if changed?
- ✓ How are destructive testing and nondestructive testing different?
- ✓ What specific techniques are used to test the quality of a 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

Modern-day industrial / commercial welding requires a very high quality standard for consistency of work produced from manufacturer to manufacturer or one side of the world to the other. We use written standards or codes to specify what is acceptable to produce high-quality weld as a means of standardizing these requirements. For the standards / codes to be effective they must be widely accepted, used, and enforced.

5.1 TESTING PROCEDURES AND CODES

Read Chapters 22 and 24 of *Welding Principles and Applications* by Larry Jeffus, 7th edition.

Today, in applications that are very high profile in nature, high stress, or high volatility, the use of welding codes / standards is very common and accepted. In low level welding applications, where production, not quality, is the driving factor, we find very little use and acceptance of the code requirements for proper welds. In these applications, the importance of production levels and consideration of cost and time required outweighs the desire to properly work within code requirements for weld quality.

There is very little enforcement of code requirements currently. A governing body does not exist to ensure following these requirements. It is left to each individual end customer to specify their requirements and to ensure that contractors live up to these requirements. The manufacturer/employer in the end is the one liable and responsible to ensure their requirements have been met.

5.1.1 PROFESSIONAL SOCIETIES THAT CREATE WELDING CODES

A number of professional societies have created and developed welding codes, specifications, and standards over the years. These are groups of individuals such as engineers, welders, inspectors, fabricators and others from related industries, which determined and continually review what it takes to make a proper weld.

Welding codes are very specific to application and type of material used. When considering which standard needs to be followed, we must refer to the blueprints and plans for the project and then consult the code the design engineer used to develop his plans. At times, this code may not be fully specified on the drawings so we must refer back to our knowledge of the applications of materials to identify the correct code. In Figure 1 below, you see a list of some major organizations that have created welding codes but the list is nowhere near an exhaustive one. The three major organizations are **AWS**, **API**, and **ASME**. Many of the others codes will reference documents that have been developed by these three particular organizations.

In Canada, the CWB is a department within the Canadian government and does act as an enforcing body for following the welding codes. The American counterpart does not have an equivalent and therefore is not enforced from a governmental level. Under some of the organizations, you will find a list of some more common codes.

AWS – American Welding Society

- D1 .1 Structural welding code – steel
    - D1 .2 Structural welding code – aluminum
- D1 .3 Structural welding code – sheet steel
- D1 .5 Bridge welding code
- D1 .6 Structure welding code – stainless steel
- D 14.1 Specification for welding earthmoving and construction equipment

API – American Petroleum Institute

- API 1104 – Welding pipelines and related facilities

ASME – American Society for Mechanical Engineers

- ASME section IX – Welding and brazing qualification

CWB – Canadian Welding Bureau

ISO – International Organization for Standardization

ANSI – American National Standards Institute

MIL-Spec – US Government Military Specification

ASNT – American Society for Nondestructive Testing

Figure 1. Welding Organizations and Codes (by Paul Phelps, CC BY 4.0)

5.1.2 IMPORTANCE OF CODES

Welding codes do not specify welding techniques. Learning how to set up the welding machine, where to stand, how the welder needs to position himself, or the technique the welder must employ to make the weld comes from a good technical education. Welding codes are critical though, as they provide the requirements for a given weld and acceptance criteria when evaluating the weld, whether visual or using different nondestructive techniques or destructive techniques. This ensures the quality, reliability, strength, and consistency of the product.

Welding codes also specify such things as: how the welder needs to be tested to qualify for the weld; the requirements of the test for the welder; and how often the welder needs to be qualified to make a particular kind of weld.

Figure 2. Typical AWS Welding Code/Specification Library (by Paul Phelps, CC BY 4.0)

5.1.3 REQUIREMENTS OF CODES

As stated previously, codes do more than tell us the requirements to make the weld to obtain the correct quality, it specifies the requirements for the welder to be qualified. The typical process for becoming qualified to weld certain types of welds is detailed in the following steps:

- ✓ The staff welding engineer or assigned AWS CWI (certified welding inspector) will create a **WPS** (welding procedure specification). The initial WPS is considered a tentative document until it is tested and proven to be able to produce welds of the required quality that meet requirements of the code.
- ✓ The next step is the WPS must be tested and proven to work. Typically, the manufacturing facility, or employer will select the best welder to weld out the first sample to test the procedure.
- ✓ The weld sample will then be tested to see if it meets the code requirements with respect to integrity, strength, penetration levels, and overall quality.
- ✓ If the weld sample fails, the procedure is to be altered and retested until a positive result is obtained.
- ✓ Once an acceptable weld is been performed, the values from when the WPS was tested are recorded in a **PQR** (procedure qualification record), and kept on file as proof of the procedure being tested and obtaining a positive result.
- ✓ The welder that welded out the initial sample and obtained the positive result is considered qualified to make this particular kind of weld automatically, without further testing of his ability being required.
- ✓ All other welders that need to produce certain kinds of welds on the job, will need to be tested in a similar manner proving their ability to make sound welds to code quality criteria.

- ✓ Each welder passing the qualification test will be awarded a **WQR** (welder qualification record), a document detailing the parameters of the test and the range of parameters the welder is allowed to work under.

The physical tests that the welder will undergo is spelled out very specifically within the code and is known as the **welder qualification** test. If everything is positive and the end result is the weld meets the criteria, the welder will be awarded a **welder certification** which provides documentation of the test parameters and results.

The code also specifies how long a welder's certification is valid. AWS D1 .1 tells us that a welder certification is good indefinitely as long as there is no period of time longer than six months in length that the welder fails to make this particular kind of weld. If the welder fails to make this kind of weld within a six-month period, the certification becomes void and requires a welder to be recertified.

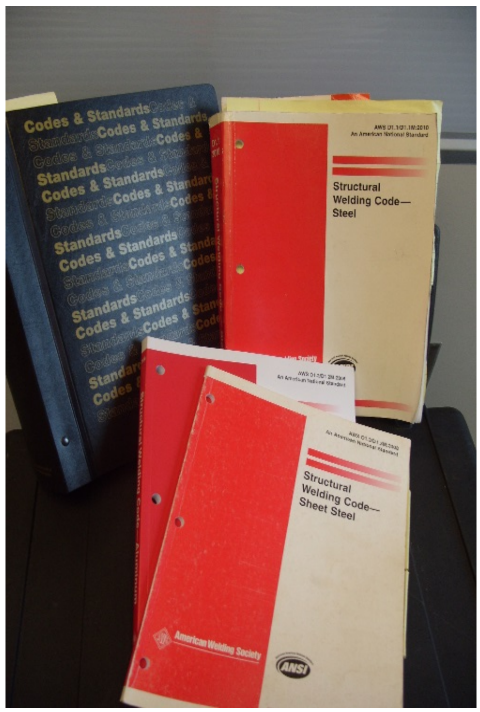


Figure 3. Examples of Specific AWS Welding Codes (by Paul Phelps, CC BY 4.0)

MODULE ACTIVITY 1

Choose the correct answer.

1. Welding codes specify actual welding techniques. T/F
2. ____________ (welder qualification, welder certification) is the actual physical tests welders have to undergo.
3. Which society is responsible for welding standards/codes?
   a. AWS
   b. ASME
   c. API
   d. All the above

There are number of other alterations to the requirements on a job that will force us to requalify the welder and the procedure. There are eight variables, which if changed for a job, will require redevelopment of the WPS, qualification of the procedure, and qualification of the welding personnel to the new WPS.

8 VARIABLES THAT REQUIRE REQUALIFICATION IF CHANGED

1. **Welding process** - The process cannot change from one welding process to another, as the skill level required to employ the different processes can be entirely different.
2. **Material type** – The material cannot change from one type to another, such as steel to aluminum or aluminum to steel, aluminum to stainless steel, stainless steel to aluminum, or any other variation. This is because welding each of these materials is entirely different.
3. **Thickness** - Each WPS has an approved thickness range that the welders have been tested and certified to work within. Therefore, if a job required workers to weld on material thicker than what was tested and approved, the welder would not be qualified for this thickness. This would require a new WPS and a new testing process to qualify welders for this WPS.
4. **Filler metal** - Each code tends to group similar types of welding filler metals whether by f number, P number, or some other type of grouping. If we need to use a filler material outside of that particular grouping that the welder is qualified for, this would require a new WPS and qualifying all of the welders to the new WPS.
5. **Shielding gas** - The composition of shielding gas or flow rate can have different effects on the weld quality. Therefore, if we step out of the flow rate range specified in the WPS or change the composition of the gas, it requires a new WPS and qualification of the welders to the new WPS.
6. **Position** - The WPS will specify what positions it can be used under, such as flat, horizontal, vertical, or overhead. Welding in different positions requires different techniques and skill levels. The code will specify what positions the welder needs to be tested in and by doing so what positions he is qualified to weld in. If the welder is required to weld in a position other than what he is qualified for, the welder must then be requalified. If the WPS when created, only tested and proved its ability to work in the flat, horizontal, and vertical positions, it would not then be qualified to be used in the overhead position.
7. **Joint design** – Typically, the code considers fillets (90° weld joints) and groove welds to be the two major classifications. Making a fillet weld and making a groove weld is completely different in the way it needs to be approached and the skill level required. Therefore, if the WPS is for a fillet weld, the welder and the procedure are not qualified to produce groove welds.
8. **Welding current** - The electrical characteristics of AC or DC are completely different and can affect the welds that are created differently. This is also true in polarity for DC currents, going from electrode negative to electrode positive. Since the current and polarity affect the weld differently and a job now requires to change current or polarity for the final product, this will require us to rewrite the WPS, qualify the WPS, and test welding personnel to this new WPS.

5.1.4 PROCEDURE QUALIFICATION RECORD (PQR)

A **PQR** (procedure qualification record) is the original version of the WPS that details the tested values while proving that the procedure works.

An example of one tested value could involve amps:

> An electrode manufacturer specified amperage for a 3/32 E7018 SMAW welding electrode is 70 to 100 amps, but the welder, testing the procedure, welded it at 90 amps. On the PQR, the recorded value would be the 90 amps the welder used while welding the test sample. Once the weld sample has been tested and proven to meet the quality standards, it then becomes the WPS to be followed throughout production and the WPS values for amperage would be 70 – 100 amps.

Figures 4 and 5 are an example of a two page, self-created version of the standard AWS WPS/PQR form out of AWS D1 .1 the structural welding code for steel.

WELDING PROCEDURE SPECIFICATION (WPS) YES☐
PREQUALIFIED ____ QUALIFIED BY TESTING ____
Or PROCEDURE QUALIFICATION RECORDS (PQR) YES☐

Company Name ____
Welding Process (es): ____
Supporting PQR No. (s): ____

Identification # ____
Revision: ____ Date: ____ By: ____
Authorized by: ____ Date: ____
Type—Manual☐ Machine☐ Semi-Automatic☐ Automatic☐

JOINT DESIGN USED
Type:
Single☐ Double Weld☐
Backing: Yes☐ No☐
Backing Material: Copper
Root Opening: ____ Root Face Dimension ____
Groove Angle: ____ Radius (J-U) ____
Back Gouging: Yes☐ No☐ Method ____

POSITION
Position of Groove: ____ Fillet: ____
Vertical Progression: Up☐ Down☐

ELECTRICAL CHARACTERISTICS
Transfer Mode (GMAW) Short-Circuiting☐ Globular☐ Spray☐
Current: AC☐ DCEP☐ DCEN☐ Pulsed☐
Other ____
Tungsten Electrode (GTAW)
Size: ____
Type: ____

BASE METALS
Material Spec. ____
Type of Grade ____
Thickness: Groove: ____ Fillet: ____
Diameter (Pipe) ____

FILLER METALS
AWS Specification ____
AWS Classification ____

TECHNIQUE
Stringer or Weave Bead: ____
Multi-pass or Single Pass (per side) ____
Number of Electrodes ____
Electrode Spacing Longitudinal ____ Lateral ____ Angle ____

SHIELDING
Flux ____ Gas ____
Composition ____
Electrode-Flux (Class) ____ Flow Rate ____
Gas Cup Size ____

Contact Tube to Work Distance ____
Peening ____
Interpass Cleaning: ____

PREHEAT
Preheat Temp., Min ____
Interpass Temp.: Min: ____ Max: ____

POSTWELD HEAT TREATMENT
Temp. ____
Time ____

WELDING PROCEDURE

		Filler Metals		Current				
Pass or Weld Layer(s)	Process	Class	Diam.	Type & Polarity	Amps or Wire Feed Speed	Volts	Travel Speed	Joint Details

Figure 4. Procedure Qualification Record
(by Paul Phelps, CC BY 4.0)

Figure 4. Example of a WPS/PQR (by Paul Phelps, Module Author)

The second page of the PQR details the testing results from the laboratory. It will specify the test parameters, test results, and required dimensional data. At the bottom of the PQR areas recording who oversaw the welding of the samples, who conducted the test of the weld sample, who reviewed the test data, and who qualified the results. At the very bottom there's a statement that the manufacturer is to sign and have on record as they accept these test results and adopt them into their standard practices.

Procedure Qualification Test (PQR) # ______
Test Results

TENSILE TEST

Specimen No.	Width	Thickness	Area	Ultimate Tensile Load, lb.	Ultimate Unit Stress, psi	Character of Failure and location

GUIDED BEND TEST

Specimen No.	Type of Bend	Results	Remarks

VISUAL INSPECTION

Appearance: ______________________
Undercut: ______________________
Piping Porosity: ______________________
Convexity: ______________________
Test Date: ______________________
Witnessed by: ______________________

Other Tests

Radiographic – ultrasonic examination
RT report no.: ________ Result: _______
UT report no: ________ Result: _______

FILLET WELD TEST RESULTS
Minimum size multiple pass Macroetch
1. _____ 2. _____ 3. _____
Maximum size single pass Macroetch
1. _____ 2. _____ 3. _____
All-weld-metal tension test
Tensile strength, psi: ______________________
Yield point/strength, psi: ______________________
Elongation in 2 in, %: ______________________
Laboratory test no.: ______________________

Welder's name: ______________________ Clock no: ___________ Stamp no.: __________
Test Conducted by: ______________________ Laboratory
Test number: ______________________
Per: ______________________

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in conformance with the requirements of Clause 4 of AWS D1.1/D1.1M, 2010 *Structural Welding Code-Steel.*

Signed: ______________________
By: ______________________
Title: ______________________
Date: ______________________

Figure 5. Test Result Page of Sample WPS/PQR (by Paul Phelps, CC BY 4.0)

5.1.5 WELDING PROCEDURE SPECIFICATIONS (WPS)

The **WPS** (welding procedure specification) seen in Figure 4, is the document detailing the requirements from the code to make the required weld. The format of the WPS is not critical in nature as long as the required information is included. Standard practice is for the original WPS to be considered tentative until it is passed through testing and is proven to produce a positive test result achieving the required quality. The WPS is the document used in the facility throughout production detailing the ranges of variables that are approved from the testing of the original WPS.

5.1.6 WELDER QUALIFICATION RECORD (WQR)

The **WQR** (welder qualification record) is the document that details the test or skill demonstration that the welder has undergone to prove their ability to produce welds that meet code quality outlined in the WPS. As previously stated, the code does give us ranges according to the tested values. For example, a welder tested on 3/8 inch plate groove weld is therefore qualified to weld on 1/8 of an inch thick material up to 7/8 inch thick material. Another example is in regards to welding positions. As tested positions can qualify welders to weld at multiple positions.

Of course to begin with, when determining which value range to use, we might need to refer back to the tables detailing this information within the code itself. In practice, many of the details tested will qualify welders to work within ranges on the job due to passing this test.

WELDER, WELDING OPERATOR, OR TACK WELDER QUALIFICATION TEST RECORD

Type of Welder ______________________
Name ______________________ Identification No. __________
Welding Procedure Specification No. __________ Rev __________ Date __________

Variables	Record Actual Values Used in Qualification	Qualification Range
Process/Type [Table 4.12, Item (1)]		
Electrode (single or multiple) [Table 4.12, Item (7)]		
Current/Polarity		
Position [Table 4.12, Item (4)]		
Weld Progression [Table 4.12, Item (5)]		
Backing (YES or NO) [Table 4.12, Item (6)]		
Material/Spec.	to	
Base Metal		
Thickness: (Plate)		
Groove		
Fillet		
Thickness: (Pipe/tube)		
Groove		
Fillet		
Diameter: (Pipe)		
Groove		
Fillet		
Filler Metal (Table 4.12)		
Spec. No.		
Class		
F-No. [Table 4.12, Item (2)]		
Gas/Flux Type (Table 4.12)		
Other		

VISUAL INSPECTION (4.8.1)
Acceptable YES or NO ______
Guided Bend Test Results (4.30.5)

Type	Result	Type	Result

Fillet Test Results (4.30.2.3 and 4.30.4.1)
Appearance __________ Fillet Size __________
Fracture Test Root Penetration __________ Macroetch __________
(Describe the location, nature, and size of any crack or tearing of the specimen.)
Inspected by __________ Test Number __________
Organization __________ Date __________

RADIOGRAPHIC TEST RESULTS (4.30.3.2)

Film Identification Number	Results	Remarks	Film Identification Number	Results	Remarks

Interpreted by __________ Test Number __________
Organization __________ Date __________

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in conformance with the requirements of Section 4 of AWS D1.1/D1.1M, (______) *Structural Welding Code—Steel.*
(year)

Manufacturer or Contractor __________ Authorized By __________

Form N-4 Date

Figure 6. Welder Qualification Record (by Paul Phelps, CC BY 4.0)

5.1.7 INTERNAL QUALITY STANDARDS

The welding code typically is considered the minimal acceptance standard. Typically, high-end employers that produce high-end products will set their own internal standards requirements. Usually, these internal standards will be much higher than the minimum to set themselves apart from their competition. This allows them to attest to the superior quality of their product.

MODULE ACTIVITY 2

Choose the correct answer.

4. Certain changes in a welding job require the job and the welder to be recertified. T/F
5. Using a filler material outside of a particular grouping that the welder is qualified for would require a new WPS and qualifying all of the welders to the new WPS. T/F
6. The ____________ (WQR, WPS) is the document detailing the requirements from the code to make the required weld.
7. What is the original version of the WPS that details the tested values while proving that the procedure works?
    a. WQR
    b. PQR
    c. AWS
    d. NDT
8. The PQR is the document that details the test or skill demonstration that the welder has undergone to prove their ability to produce welds that meet code quality. T/F
9. The welding code is considered the ultimate acceptance standard. T/F

5.2 DESTRUCTIVE TESTING

Read Chapter 23 (pages 575 – 593) of *Welding Principles and Applications* by Larry Jeffus, 7th edition.

When determining weld quality, we can use two different types of testing methods for verification of the integrity of the produced welds as well as the ability of the welder. Destructive testing and nondestructive testing are used at different times for different reasons. In the following sections, we will detail the different techniques, reasons used, and what they achieve.

Destructive testing, as the name implies, physically destroys the sample weld as part of the testing process, leaving it unusable. The different testing techniques can test different strength measurements and verify the integrity of a weld. Destructive testing is used in the laboratory for qualifying welding procedures, testing materials, testing welds, and/or testing design. Some forms of destructive testing are part of the welder qualification process.

5.2.1 TENSILE TESTING

Tensile strength is a very common term to welding and is used in electrode classifications. Tensile strength is a measurement of pulling force a material can withstand before failure. Tensile testing for good consistent weld results must be treated just like a scientific experiment. This means that all weld samples to be tested must be very uniform in preparation, and the manner in which we conduct the test to be very scientific in nature.

In Figure 7 below, you see two main types of tensile specimens. On the left, are the normal round tensile specimens, while on the right, are the produce section tensile specimens. The round tensile specimens are turned on a lathe to a specific diameter and length, with threads on the ends where they will attach to the pulling fixture in the testing equipment. The reduced section tensile specimen on the right shows flat notched specimens designed to be used with serrated grips. The flat notches on the sides create a very consistent square inch of area to be tested.

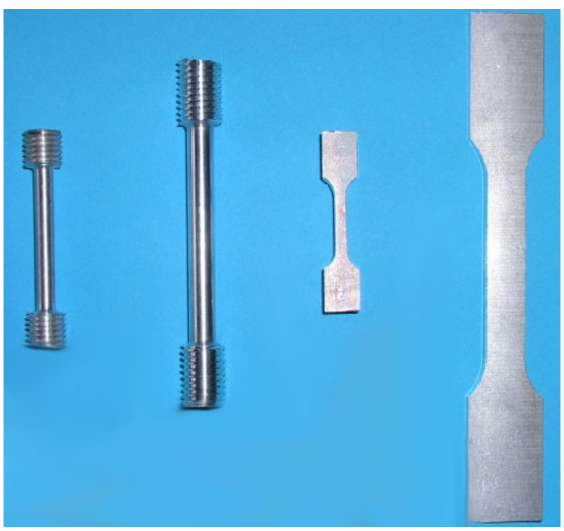


Figure 7. Two Types of Tensile Specimens (Wizard191, CC BY-SA 3.0)

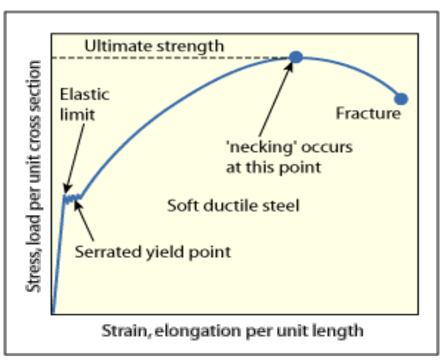
EXPLORE: [Tensile Testing]

EXPLORE: [Mechanical Testing – Tensile Testing]

Figure 8 is a tensile testing piece of equipment. In the center, you see the material to be tested clamped between the upper and lower jaws. The machine will apply pulling force with the bottom jaw moving upward and the bottom jaw staying in a fixed position. As the material is pulled, the force is applied at a constant rate and measured. These measurements are taken throughout the test to understand at what point changes take place. This information leads to an understanding of the elasticity of the metal. In layman's terms, when we apply the pulling force partially and then remove the force, the material springs back to its original position, much like the elastic waistband on your underwear. Though, just like your waistband, there are limits to how far it can stretch before it stops bouncing back.

Figure 8.Tensile Testing Machine
(by Kerina yin, Public Domain)

In Figure 9, you see a graph and a diagram that shows the point where a material loses its elastic properties and begins to stretch. As the material stretches, it starts to reduce in cross-sectional size and does what is known as necking down. As forces continue to be applied to the material, it will reach the final breaking point where it fails. Through this process, we are able to measure and determine a material's elastic limit, the yield point, the yield strength, its ultimate strength, and finally how much force the material can undertake before complete failure.



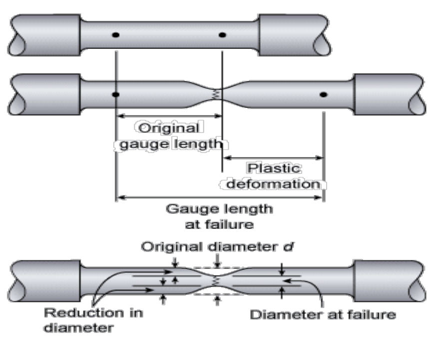


Figure 9. Representations of the Tensile Testing Process to a Failure/Fracture Point (by John Mathers, "Courtesy of TWI Ltd")

MODULE ACTIVITY 3

Choose the correct answer.

10. There are testing methods for verification of the integrity of the produced welds as well as the ability of the welder. T/F
11. What are the testing methods called?
    a. Positive, Negative
    b. Tensile, Malleable
    c. High risk, Low risk
    d. Non-destructive, Destructive
12. _________ (tensile strength, weld integrity) is a measurement of pulling force a material can withstand before failure.
13. One is able to measure and determine a material's elastic limit, the yield point, the yield strength, and its ultimate strength through destructive testing. T/F

5.2.2 FATIGUE TESTING

Fatigue testing is used to determine how a weld sample performs under repeated varying stresses and to measure what the material can withstand before complete failure. Have you ever taken a piece of sheet metal bended back and forth until it completely failed? You fatigued the metal to its failing point. Depending on what is to be measured the sample may be twisted or as the example of that piece of sheet metal, bent back and forth to see what it can withstand. The results can be correlated to the usefulness of the weld with regards to the conditions it will be subjected to.

Another example of fatigue testing can be seen in a test new vehicle models go through. We've seen the commercials on television where they have each vehicle tire on a pedestal. The tire is subjected to a plunging up-and-down motion which tests the suspension. This test is to try and replicate extreme circumstances that the vehicle may encounter out on the road. The engineers want to know how many cycles the suspension components can withstand before they fail.

The concept is very similar to that with welds. As force is applied, whether twisting or bending, we try to infer and understand exactly what load the weld can withstand before failure. Figure 10 shows a typical fatigue crack growth rate.

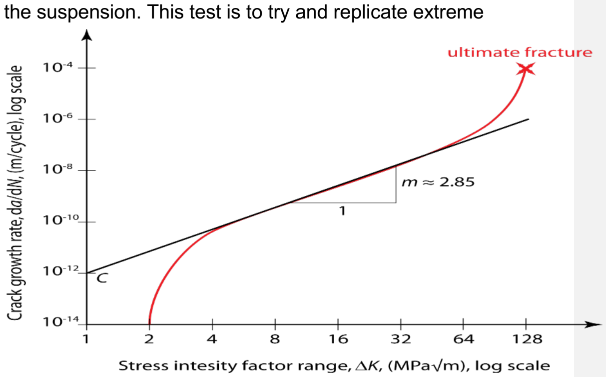


Figure 10. Typical Fatigue Crack Growth Rate Graph
(by Tomeasy, CC BY-SA 3.0)

Video 1 – Click on the video icon to watch a detailed overview of fatigue testing and some of the additional variables that can affect the way the material performs such as weld discontinuities like porosity, inclusions, inadequate joint penetration, cracks, or even surface conditions of the material.(by Learn Engineering, Standard YouTube License)

MODULE ACTIVITY 4

Choose the correct answer.

14. Bending a piece of sheet metal back and forth until it completely failed is an example of ______ (fatigue, tensile) testing.
15. The integrity of a weld can be dependent on the conditions the weld will be subjected to. T/F

5.2.3 SHEAR TESTING

When you hear the term shear, you may visualize a pair of scissors. Shears is the old-school term for scissors and is an example of two planes going in opposite directions and anything caught in between can be cut apart. The concept is the same for industrial shears used for cutting plate or sheet-metal with a bottom fixed blade and an upper blade being hydraulically activated to create the downward force. As the two blades pass each other, anything in between will be cut in two.

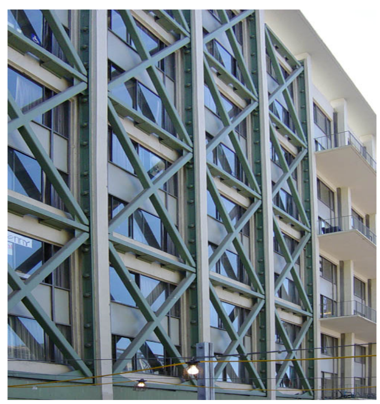


Figure 11 Shear Trusses
(by Leonard G, CC SA 1.0)

Shear strength has a few very important considerations when it comes to welds or engineering design. In the structural steel business (see Figure 11), it is important to understand the limitations of bolts or fasteners. If the strength of the bolts holding a connection together is too low, the two planes of the connection, going in opposite directions, will cut the bolt in half. In the welding world, the finished weld is replacing the bolt for the connection of the two planes traveling in two different directions. This is why shear testing is important. If the weld quality is inadequate, it will not be able to hold up to the load, just like the bolt that was used in the connection failed.

So shear testing allows us to identify exactly what size weld may be required to live up to the applied load and then test this in a laboratory to verify that this is true. When talking about shear testing, there are two different types shearing forces, longitudinal shear and transverse shear. The type depends on which way the force is being transferred across the weld joint itself. Shear testing allows us to mock up the load, keeping one member in place and then applying force to the connection. By creating the shearing force, we can measure how much force it can withstand up to the failure point.

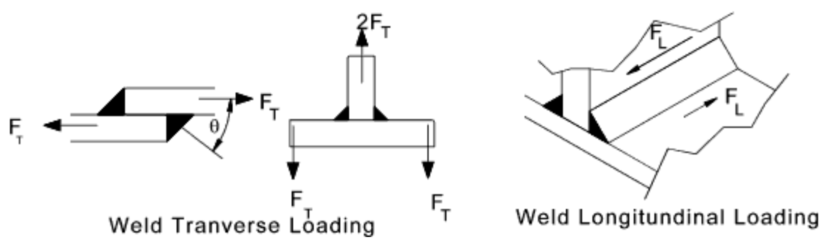


Figure 12. Diagrams of Transverse and Longitudinal Shear Loads
(by Roy Beardmore, Public Domain)

MODULE ACTIVITY 5

Choose the correct answer.

16. Shears involves two planes going in opposite directions and anything caught in between can be cut apart. T/F
17. Shear testing allows us to identify exactly what size weld may be required to live up to the applied load. T/F
18. The two types of shearing forces are:
    a. Vertical , Horizontal
    b. Transverse, Longitudinal
    c. Upward, Downward
    d. Inward, Outward

EXPLORE: Destructive Testing

5.2.4 NICK BREAK TEST

The Nick break test is used to test welded butt joints and the integrity of the weld joining these two plates. The weld specimens to be tested are prepared as in Figure 13. The notches that are cut in the center of the weld create a weak point so there can be a controlled failure between the two notches. The weld sample then goes into the testing equipment as shown in Figure 14. The ram or hammer, located directly above then sample, begins pushing down causing a forced but controlled failure of the weld specimens. Depending on the intent of the test, the force can be very quick to achieve failure or it can be very slow. The amount of force that leads to failure is measured for each process. Either process allows us to look for imperfections such as slag inclusions or other defects within the internal structure of weld itself.

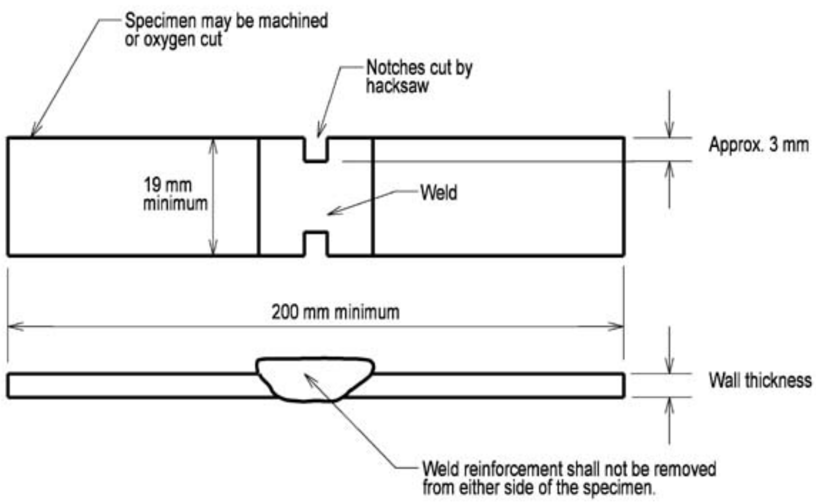


Figure 13. Diagram of Nick Break Test Set-up
(by Unknown, Public Domain)

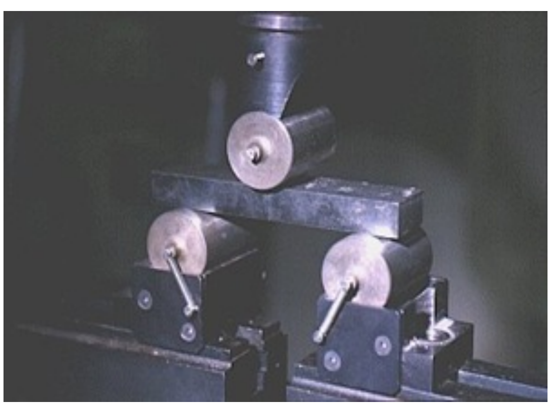


Figure 14. Picture of Nick Break Testing Equipment (by Unknown, Public Domain)

5.2.5 GUIDED BEND TEST

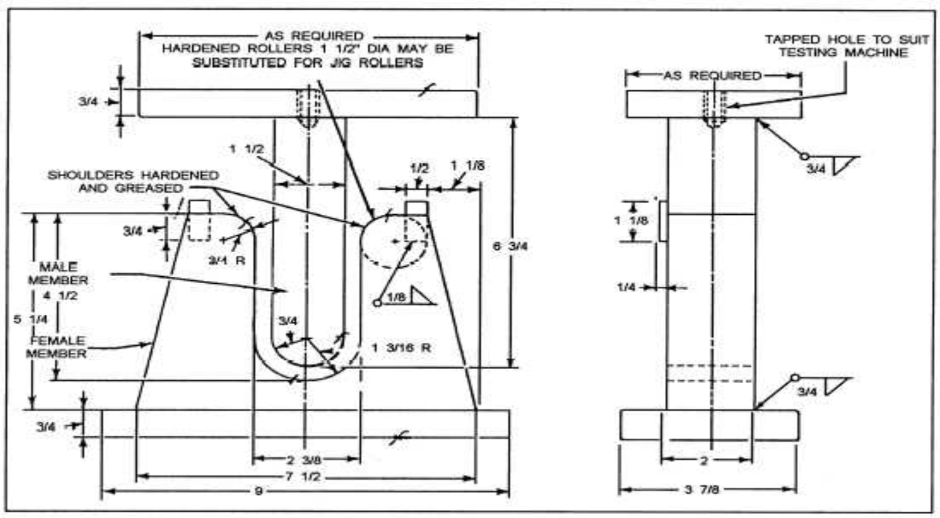


Figure 15. Guided Bend Test Specifications (by Unknown, Public Domain)

Guided bend tests provide a quality control check that helps determine the ductility of weld metal at the face and root of a welded joint. Figure 15 shows a guided bend test and its specifications. The guided bend test is very precise with regards to the radius of the bent specimen. The test creates a uniform amount of stress on the weld sample. Done properly, it yields very consistent results while testing the integrity of the weld. A guided bend test is commonly used for welder qualification for a groove welded butt plate. On a section of test plate, once the weld is completed and fully cool, two straps will be cut out of each welded plate. The location and dimensions of this weld sample are very precise as required by the code. For each position requires us to bend one forward and one backwards from the same sample, to look at the face of the weld and the root of the weld (see Figure 16).

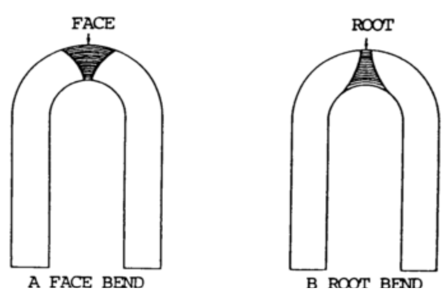


Figure 16. Guided Bend Test Specimens
(by Unknown, Public Domain)

In the event that there are any imperfections in the weld metal they will break out to the surface as you can see in Figure 17. Any imperfections of break out on a convex surface is visually examined and measured against the criteria spelled out by the welding code.

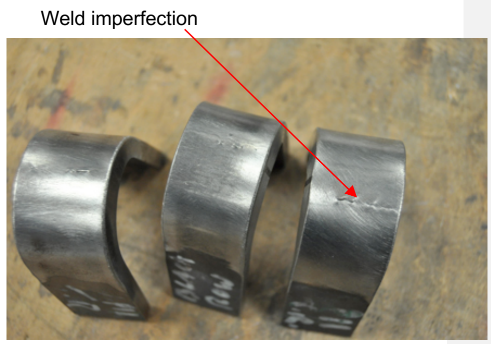


Figure 17. Weld Imperfection in a Guided Bend Test Specimen (by Unknown, Public Domain)

Video 2 – Click on the video icon to watch a video about guided bend tests. (by Paul Phelps, Standard YouTube License)

5.2.6 FREE BEND TEST

The free bend test is also used for welder qualification for a groove welded butt plate. The plates will resemble that for guided bend test in preparation but they require additional preparation by laying out scribe lines on the surface of the weld. Some welders feel that the free bend is not as consistent and precise as the guided bend and requires some additional work with the scribe lines. The purpose of the scribe lines is to take measurement and understand how far the weld is stretched through the bending process.

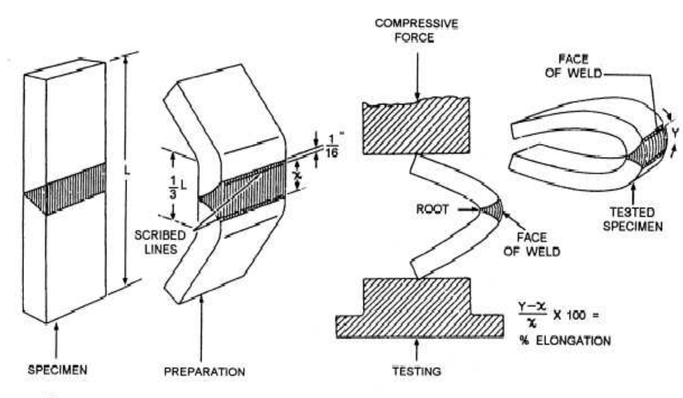


Figure 18. Free Bend Test (by Unknown, Public Domain)

MODULE ACTIVITY 6

Choose the correct answer.

19. The free bend test is used to test welded butt joints and the integrity of the weld joining these two plates. T/F
20. The purpose of scribe lines is to take measurement and understand how far the weld is stretched through the bending process. T/F
21. A ____________ (guided bend, free bend) test provide a quality control check that helps determine the ductility of weld metal at the face and root of a welded joint..
22. Weak points are created in the Nick Break test by using
    a. Notches
    b. Electrodes
    c. Inclusions
    d. Nodes

5.2.7 FILLET BREAK TEST

This test is performed to reveal internal imperfections such as slag inclusion, lack of fusion, incomplete penetration, porosity, etc in a fillet weld. A fillet weld specimen is fractured along an artificial notch that is intentionally machined on the center line of the fillet weld specimen to facilitate fracture in the center of the weld. The fractured specimen cross section is then visually examined for imperfections.

The fillet break test is also used many times for WPS qualification and/or welder qualification, specifically for fillet welds. Figure 19 shows the welded section and the required dimensions. Note the requirement for a stop and restart welding near the center of the welded plate. Once completed, one section will be cut off of each end and that will be used for the macroetch specimens which to be discussed in the next section.

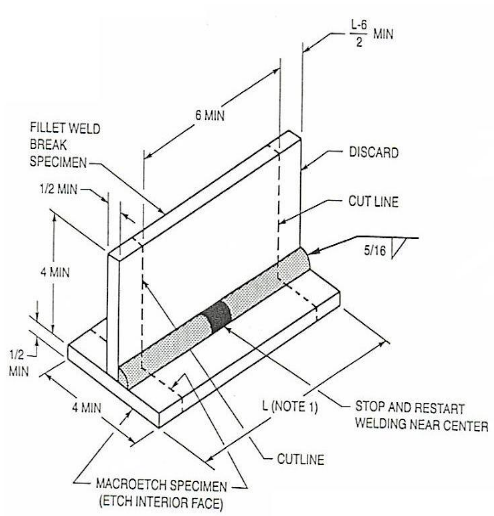


Figure 19. Fillet Weld Break and Macroetch Test Plate (by Unknown, Public Domain)

Once these two cuts have been made and removed, the center section will be placed in a test fixture and force applied from the top down as shown in Figure 20. The code requirement is for the two plates to be pushed until they are parallel with each other. The force to be applied can be delivered by a mechanical ram such as a hydraulic press or a sledgehammer. Once the plates are bent over on top of themselves, we evaluate the underside of the weld, looking for any imperfections such as inclusions or lack of weld penetration. Any and all imperfections will be measured against the criteria spelled out within the code.

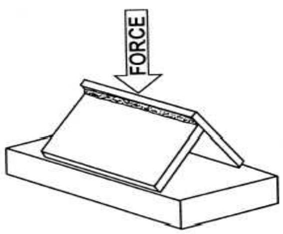


Figure 20. Rupturing Fillet Weld Test Plate
(by Unknown, Public Domain)

5.2.8 ACID ETCH TEST

The macro etch test can easily show the depth of weld penetration into the base metal. Even though we show an edge of a fillet weld, the test can be used for most any welded joint by cutting a cross-section and going through the process of etching the material. The process calls for us to highly polish the cut area of the cross-section and apply acid, which energizes the weld metal so that we can see the difference in color and the amount of weld penetration. Different materials require different types of acid to be used to gain the chemical reaction needed. You would need to refer to the code requirements for specific dilution mixtures. For example, with carbon steel use a diluted nitric acid solution and on aluminum, you could use a popular oven cleaner spray. The trick with an acid etch test is to apply the acid while the material is still hot from the grinding and polishing. After the acid has been on the material for a few minutes but before it dries, it needs to be washed in clean water. By this time, the weld should show a visible difference in color from the base and the level of penetration should be obvious.

Figure 21. Macro Etch Test Weld (by Unknown, Public Domain)

Video 3 – Click on the video icon to watch a video about fillet break and acid etch testing. (by Paul Phelps, Standard YouTube License)

5.2.9 IMPACT TESTING

The process of impact testing is where a sudden amount of force is applied to the welded sample, testing the integrity of the weld. There are two common types of impact testing, Izod and Charpy V-notch. With both testing methods, multiple samples are cut out of the welded section and then precisely machine with a notch or relief cut to create a control failure point.

The Charpy V-notch test, is a standardized test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of the material's notch toughness. This test is easy to prepare and conduct and results can be obtained quickly and cheaply. Many times with the Charpy V-notch, they will test samples at different temperatures to understand how the material and welds will react at different temperatures. This can be very important for the engineer who has to take environment temperatures into account when selecting materials and weld joint designs.

Izod impact testing is another method of determining the impact resistance of materials. An arm held at a specific height is released. The arm hits the sample. The specimen either breaks or the weight rests on the specimen. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity. This test is similar to the Charpy test but it uses a different specimen arrangements.

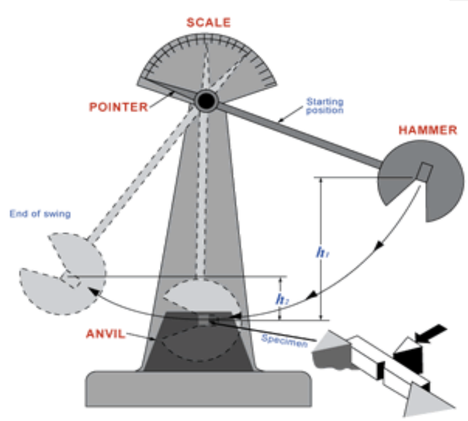


Figure 22. Impact Toughness Test
(by Unknown, Public Domain)

EXPLORE: Impact Toughness

Field Code Changed

EXPLORE: Mechanical Testing of Materials

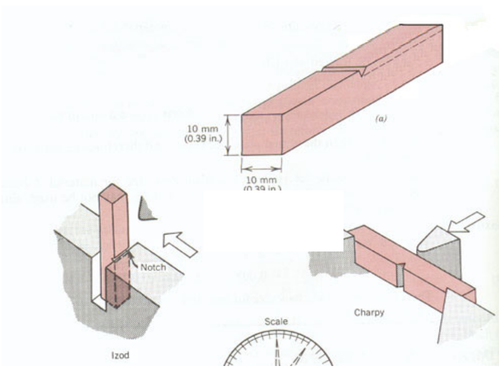


Figure 23. Illustration of Charpy and Izod Impact Tests
(by Callister W.D. Jr., Public Domain)

MODULE ACTIVITY 7

Choose the correct answer.

23. A fillet weld specimen is fractured along an artificial notch that is intentionally machined on the center line of the fillet weld specimen to facilitate fracture in the center of the weld. T/F
24. In the acid etch test, one type of acid is used for all type materials to gain the chemical reaction needed. T/F
25. Impact testing is where a sudden amount of force is applied to the welded sample, testing the integrity of the weld. T/F
26. The ____________ (fillet break, macro etch) test shows the depth of weld penetration into the base metal.
27. Which answer is a type of impact testing?
    a. Nautica
    b. Izod
    c. Lauren
    d. Chaps
28. Welded material samples will be tested at different temperatures to understand how the material and welds will react at different temperatures in the Charpy V-notch test. T/F

5.3 NONDESTRUCTIVE TESTING

Nondestructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage. Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. NDT has become a big business and is critical on the job site. Today there are a number of techniques that allow us to look at the surface very closely, and look internally to the weld verifying the quality and integrity. In this section, we will detail the nondestructive testing methods that are used in the field. To use these techniques in the field, requires proper certification or the test results will not be accepted. The American Society for Nondestructive Testing (ASNT) sets the standard for NDT processes. There are several levels for each process. A level I, II, or III exists for each process, with three being the expert professional in that given process. The ASNT has very strict requirements for how many hours of training and experience are required with the process, before testing and moving up to any given level.

EXPLORE: Non-Destructive Testing

5.3.1 VISUAL INSPECTION (VT)

Visual inspection is the first and most important NDT technique. It should be used before any other time or effort is put into the evaluation and inspection of the component. The welder is the first line of inspection. They should evaluate their work to determine if the weld meets the visual inspection criteria that is outlined very clearly in the code.

Figure 24. Visual Inspection (by Unknown, Public Domain)

Video 4 – Click on the video icon to watch a video about visual inspection. (by Paul Phelps, Standard YouTube License)

5.3.2 DYE PENETRANT TESTING (PT)

Dye penetrant testing is a very simple but effective technique to identify weld surface imperfections (Figure 25). Some feel the test is limited though because it can only detect open surface flaws. The die penetrant inspection components, penetrant, cleaner, and developer, usually come in kit. The process requires the surface to be cleaned using the supplied cleaner to remove any grease or foreign materials from the surface. Once the surface is thoroughly cleaned, the die penetrant is applied. Any open defect on the surface will absorb the die in a capillary type action. After a designated amount of time, the excess dye will be cleaned away. Next we apply a heavy coat of the developer which will appear as a white powder covering the surface. The dye that was absorbed into the open defect will be drawn out and be evident against the white background. The defect is then documented and measured and a determination is made whether the weld is acceptable or not. The final step is cleaning away any dying developer that was left behind. Sometimes a florescent dye that is visible under a black light is used (Figure 26).

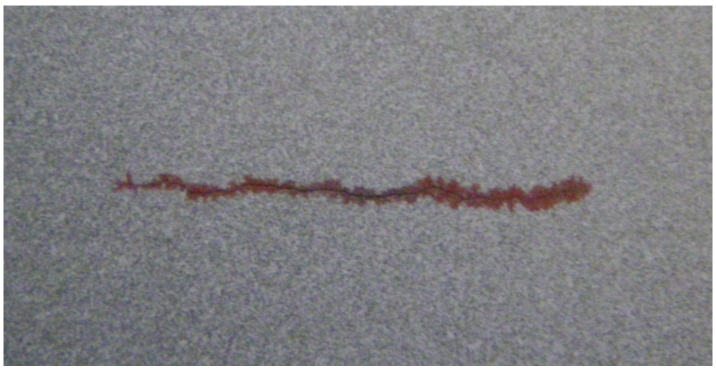


Figure 25. Results of Dye Penetrant Test (by Unknown, Public Domain)

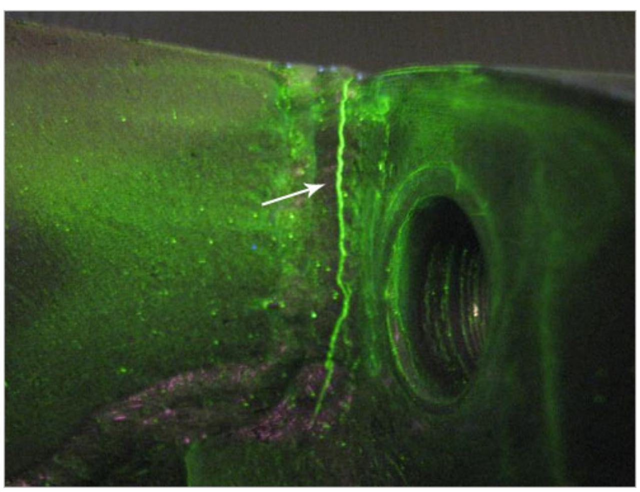


Figure 26. Example of Fluorescent Penetrant Inspection (by Unknown, Public Domain)

EXPLORE: [Dye Penetrant Testing]

MODULE ACTIVITY 8

Choose the correct answer.

29. Dye penetrant testing is a simple but effective technique to identify weld surface imperfections. T/F
30. ____________ (Visual inspection, Dye penetrant testing) is the first and most important NDT technique.

5.3.3 MAGNETIC PARTICLE TESTING (MT)

Magnetic particle testing is a fairly simple technique but does require understanding of the technique to get good results. The equipment required is a large magnet, known as the yoke, with the two poles (north and south) of the magnet. When the poles come in contact with the magnetic piece to be tested, magnetic fields are created as the electricity passes from one pole to the other. In the event there is a defect or impurity in the path of that magnetic field when we apply magnetic powder, the particles will be attracted to the imperfection or crack. To fully test the component when we must approach it at multiple angles with the yoke to make sure that the defect or impurity doesn't align itself with the magnetic poles we want to be perpendicular so that it will stand out and the particles will be drawn to it. This is a very common process in pipe inspection. Figure 27 is a close-up of the surface of a pipeline showing indications of stress corrosion cracking (two clusters of small black lines) revealed by magnetic particle inspection. Cracks which would normally have been invisible are detectable due to the magnetic particles clustering at the crack openings.

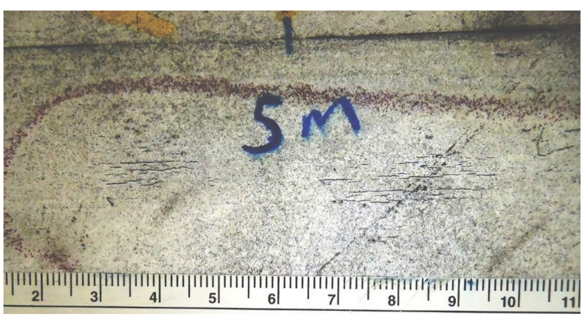


Figure 27. Example of Magnetic Particle Inspection (by Davidmack, CCO)

5.3.4 RADIOGRAPHIC TESTING A.K.A. X-RAYS (RT)

Please review Chapter 23, pages 585 – 589 in Welding Principles and Applications by Larry Jeffus 7th edition, for examples of x-rays and multiple discontinuities that are represented.

Radiographic testing, a.k.a. x-ray, has the ability to take an image looking through the work piece. Radiographic inspection allows us to get a complete view of the finished weld. It is a very controlled technique because of the radioactive isotope that produces the x-rays that pierce the part. These rays can be hazardous and damage or kill human flesh and actually kill an individual if the radiation exposure is high enough. The technique is very similar to having bones x-rayed at the doctor's office. For the welding industry, it is a mobile and much more compact process so it can be used on the job site. But as stated earlier, it has to be very controlled to protect everyone working in that area. One downside to radiographs are the fact that they can be difficult to interpret and require a lot of training to be able to properly interpret them. Also radiographs interpretation is a subjective opinion of the individual that is evaluating the x-ray film.

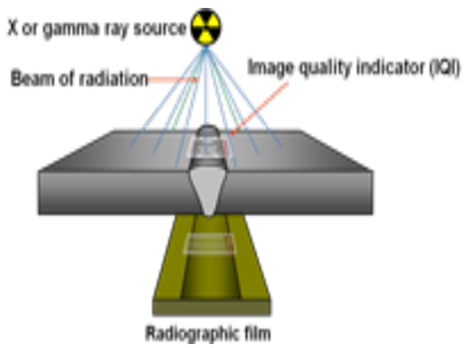


Figure 28. Principles of Radiography
(by Unknown, "Courtesy of TWI Ltd.")

X-rays make it very easy to identify, measure, and locate where the imperfection is in the piece. With this benefit, they can aid us in making needed repairs. Modern-day advancements have allowed for use of digital x-rays in our field. With digital x-rays, the results are much faster, easier to manage, and less costly since the results are digital in form and can be on any computer and simply emailed from one person to another.

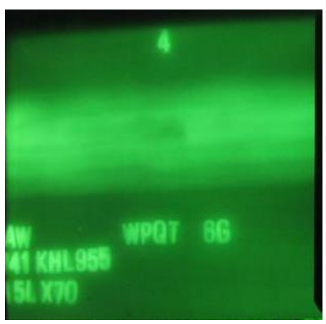


Figure 29. Weld Radiograph with Burn through Defect
(by Bernoullies, CC BY-SA 3.0)

MODULE ACTIVITY 9

Choose the correct answer.

31. Radiographic testing is a very common process in pipe inspection. T/F
32. Radiographic inspection allows us to get a complete view of the finished weld. T/F
33. Pipe cracks which would normally be invisible are detectable due to________ (magnetic particles, fluorescent dye) clustering at the crack openings in one NDT process.
34. What are the advantages of using radiographic testing?
    a. Portable

b. Less expense
c. Faster results
d. All the above

35. Magnetic particle testing equipment is simple and inexpensive. T/F

5.3.5 ULTRASONIC TESTING (UT)

Ultrasonic testing, also known as UT, uses sound waves passing through a part as a testing method. If the sound waves come in contact with something other than the base metal itself, such as a discontinuity or defect, the sound wave will be disrupted and change its pattern. The operator can change the frequency of the sound wave to control the intensity and how far travels. Ultrasonic testing is a desirable testing method since it is inexpensive compared to others and is also portable and accurate. Outside of the main control unit, you have the probe, transducer, couplant, and piece to be tested. The couplant is a gel that helps the transducer to make contact with the part and make for a better transmission of the sound waves into the particle being tested.

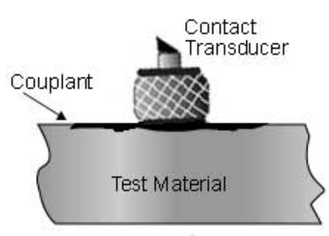


Figure 30. Couplant (by Unknown, Public Domain)

The transducer is basically what focuses the sound waves into the part. Advancements are being made in ultrasonic testing with what is known as phased array. This is becoming the desired technique because it is much faster.

Ultrasonic testing allows us to take repeated measurements and pinpoint the location of the defects so accurate measurements can be taken not only lengthwise but also how deep the defect is within the part. This allows us to make very effective repairs quickly.

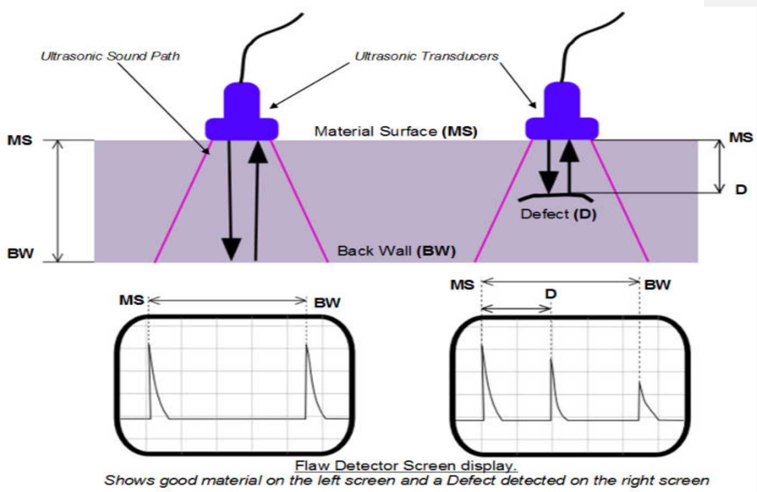


Figure 31. Diagram of Ultrasonic Flaw Detection (by Unknown, Public Domain)

Figure 32. Example of Ultrasonic Testing (by Plenumchamber~commonswiki, CC BY-SA 3.0)

EXPLORE: [Ultrasonic Weld Testing]

EXPLORE: [Phased Array]

5.3.6 LEAK TESTING

Leak testing is a very simple but very effective technique. This test allows us to pressurize a system and visually look for leaks. One advantage is usually in systems using hazardous gases, we can conduct the test using nonhazardous gases to determine where the leak is. For example, it is very common in the HVAC field, to fill an AC unit with nonhazardous nitrogen gas, instead of Freon, to test for leaks, as Freon is hazardous to the atmosphere. Also, many times our hazardous gases are also flammable. Therefore it is much safer to use compressed air and soapy water on lines or components and look for bubbles where the air is escaping. Once a leak is identified, we can make the needed repairs and get the system back online fairly quick.

Figure 33. Leak Testing
(by Paul Phelps, CC BY-SA 4.0)

MODULE ACTIVITY 10

Choose the correct answer.

36. An advantage to leak testing in systems using hazardous gases, is being able to conduct the test using nonhazardous gases to determine where the leak is. T/F
37. In ultrasonic testing, ________ when (x-rays, sound waves) come in contact with something other than the base metal itself, such as a discontinuity or defect, there will be a disruption and change in a pattern.
38. Which answer below is a gel that helps the transducer to make contact with the part and make for a better transmission of the sound waves into the particle being tested?

a. Transducer
b. Eddy
c. Couplant
d. Nodular

5.3.7 EDDY CURRENT TESTING (ET)

Eddy current testing is a merge of magnetic particle and ultrasonic testing into one process. Magnetic fields and eddy currents are used to identify where a defect within a material may lie, using a display similar to that of the ultrasonic tester displaying the pathway of the magnetic field. In a standard eddy current testing, a circular coil carrying current is placed in proximity to the test specimen (which must be electrically conductive). The alternating current in the coil generates a changing magnetic field which interacts with test specimen and generates eddy current. Variations in the phase and magnitude of these eddy currents can be monitored. Variations in the electrical conductivity or magnetic permeability of the test object, or the presence of any flaws, will cause a change in eddy current and a corresponding change in the phase and amplitude of the measured current.

Limitations to the process include: only conductive materials can be tested; the surface of the material must be accessible; the finish of the material may cause bad readings; the depth of penetration into the material is limited by the materials' conductivity; and flaws that lie parallel to the probe may be undetectable.

Advantages to the process include: ability to detect very small cracks in or near the surface of the material; the surfaces need minimal preparation; and physically complex geometries can be investigated. It is also useful for making electrical conductivity and coating thickness measurements. Also, the testing devices are portable, provide immediate feedback, and do not need to contact the item in question

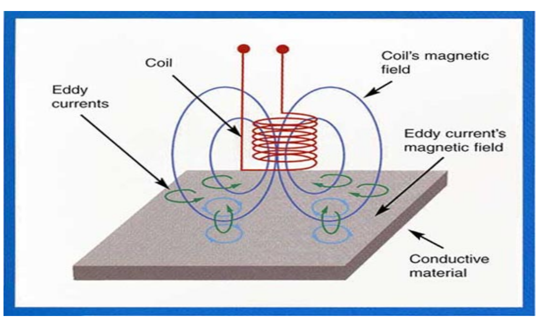


Figure 34. Eddy Current Testing (by Unknown, Public Domain)

Figure 35. Eddy Current Testing on a Piece of Aluminum (by Jason Church, Public Domain)

5.3.8 HARDNESS

In metal working, hardness generally implies resistance to penetration. Indentation hardness is probably the most widely used mechanical testing procedure and it is relatively inexpensive, and can be done by semi-skilled operators. Hardness tests are used for specification purposes, to check heat treating procedure, to check the effectiveness of surface-hardening methods and as a substitute for tensile tests on parts that are too small for full scale tests. There are a number of hardness testing methods; however, two of the most commonly used are the Brinell and Rockwell methods.

The Rockwell tester uses a diamond cone or steel ball which is pressed into the base metal. The impression left by the penetrator pressing into the base is measured and can tell us how hard the material is. Remember hardness is a measurement of materials resistance to penetration.

Brinell systems uses a metal ball pressed into the material at a consistent load of 3000kg for 30 seconds leaving in indentation. The hardness of the material is determined by measurement of the indentation. The indentation is measured microscopically to determine the hardness.

EXPLORE: NDT Method Summary

MODULE ACTIVITY 11

Choose the correct answer.

39. With hardness testing, variations in the electrical conductivity or magnetic permeability of the test object, or the presence of any flaws, will cause a change in eddy current and a corresponding change in the phase and amplitude of the measured current. T/F
40. In ___________ (Rockwell, Brinell) testing, the hardness of the material is determined by the measurement of the indentation caused by the metal ball.
41. One advantage of eddy current testing is
    a. Only conductive materials can be tested.
    b. Flaws that lie parallel to the probe may be undetectable.
    c. The depth of penetration into the material is limited by the materials' conductivity.
    d. The ability to detect very small cracks in or near the surface of the material
42. The Rockwell tester uses a diamond cone or steel ball which is pressed into the base metal. T/F

MAJOR CONCEPTS

KEY CONCEPTS

- Welding codes are critical, as they provide the requirements for a given weld and acceptance criteria when evaluating the weld. This ensures the quality, reliability, strength, and consistency of the product.
- Welding codes also specify the requirements for a welder to be qualified and there is a specific process that must be followed.
- There are number of other alterations to the requirements on a job that will force us to requalify the welder and the procedure. There are eight variables, which if changed for a job, will require redevelopment of the WPS, qualification of the procedure, and qualification of the welding personnel to the new WPS.
- There are welding procedure specification documents that are required, as they provide the necessary details from the welding code to make the appropriate weld.
- When determining weld quality, we can use two different types of testing methods for verification of the integrity of the produced welds as well as the ability of the welder. Destructive testing and nondestructive testing are used at different times for different reasons.
- Destructive testing techniques (tensile, fatigue, shear, nick-break, guided-bend, free-bend, fillet break, acid etch, impact) physically destroy the sample weld as part of the testing process, leaving it unusable.
- Nondestructive testing (NDT) is a wide group of analysis techniques (visual, dye penetrant, magnetic particle, radiographic, ultrasonic, leak, eddy current, hardness) used in science and industry to evaluate the properties of a material, component or system without causing damage.

KEY TERMS

PQR
WPS
WQR
AWS
ASME
ASNT
API
welder qualification
welder certification

ASSESSMENT

MODULE REINFORCEMENT

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

____ 1.Nondestructive and destructive testing verify the integrity of the weld and the ability of the welder.
____ 2. Acid is applied to a test specimen in etch testing.
____ 3. Izod and Charpy V-notch tests are used for the NDT technique of impact testing.
____ 4. Penetrant testing is the most frequently used NST method.
____ 5. Visual inspection detects flaws just below the surface of magnetic parts.

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

____ 1. Which organization has the most commonly used welding codes?
a) AWS
b) API
c) ASME
d) All the above

____ 2. The ____ is the written instructions by which a sound weld is made.
a) DST
b) PQR
c) WQR
d) WPS

____ 3. The ____ is the tentative version of the welding procedure specification that details the tested values while proving the weld is sound.
a) WPS
b) PQR
c) WQR
d) NDT

____ 4. Which answer is not an essential variable that causes the need to recertify a project?
a) Position
b) Inclusion
c) Material
d) Thickness

____ 5. This document is helpful when you want to compare a completed weld to the welding standard.
a) WQR
b) PQR
c) WPS
d) NDT

____ 6. The two main types of tensile specimens are____.
a) Round bars and flat strips
b) Oblong blocks and square rods
c) Flat strips and oblong blocks
d) Round bars and square rods

____ 7. Tensile testing, fatigue testing, and shear testing measure a material's ____.
a) Hardness
b) Brittleness
c) Failure point
d) Weld penetration

____ 8. Welded butt joints are tested by which test?
a) Nick-break
b) Guided-bend
c) Free-bend
d) All of the above

____ 9. ____ is a method for detecting flaws inside weldments.
a) Magnetic particle inspection
b) Impact testing
c) Visual inspection
d) Radiographic inspection

____ 10. There are ____ types of hardness testing machines.
a) 2
b) 3
c) 4
d) 5

Completion: Complete each statement.

1. ________ _________ is used to locate minute surface cracks and porosity.

2. ________ _________ causes damage to a part being tested.

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

1. Differentiate between a welding code and a welding specification.

2. Describe what hardness testing measures.

ANSWER KEY TO MODULE ACTIVITIES

ACTIVITY 1

1. F
2. Welder qualification
3. d

ACTIVITY 2

4. T
5. T
6. WPS
7. PQR
8. WQR
9. F

ACTIVITY 3

10. T
11. d
12. tensile strength
13. T

ACTIVITY 4

14. fatigue
15. T

ACTIVITY 5

16. T
17. T
18. b

ACTIVITY 6

19. F
20. T
21. Guided bend
22. a

ACTIVITY 7

23. T
24. F
25. T

26. Macro etch
27. b
28. T

ACTIVITY 8

29. T
30. Visual inspection

ACTIVITY 9

31. F
32. T
33. Magnetic particles
34. d
35. T

ACTIVITY 10

36. T
37. Sound wave
38. c

ACTIVITY 11

39. F
40. Brinell
41. d
42. T

ANSWERS TO ASSESSMENT QUESTIONS

TRUE/FALSE (textbook page reference)

1.	ANS:	T	PTS:	1	REF:	568
2.	ANS:	T	PTS:	1	REF:	582
3.	ANS:	F	PTS:	1	REF:	582-583
4.	ANS:	F	PTS:	1	REF:	583
5.	ANS:	F	PTS:	1	REF:	584

MULTIPLE CHOICE

1.	ANS:	d	PTS:	1	REF:	551
2.	ANS:	d	PTS:	1	REF:	552
3.	ANS:	b	PTS:	1	REF:	5552
4.	ANS:	b	PTS:	1	REF:	597
5.	ANS:	a	PTS:	1	REF:	633
6.	ANS:	a	PTS:	1	REF:	575
7.	ANS:	c	PTS:	1	REF:	575-577
8.	ANS:	d	PTS:	1	REF:	577
9.	ANS:	d	PTS:	1	REF:	585
10.	ANS:	a	PTS:	1	REF:	591

COMPLETION

1. ANS: Penetrant inspection

PTS: 1 REF: 583

2. ANS: Destructive testing

PTS: 1 REF: 575

SHORT ANSWER

1. ANS: A welding code is a detailed listing of rules or principles that are to be applied to a specific classification or type of product. A welding specification is a detailed statement of the legal requirements for a specific classification or type of weld to be made on a specific product.

PTS: 1 REF: 550

2. ANS: Resistance of metal to penetration which indicates the metal's wear resistance and strength

PTS: 1 REF: 591

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