Objectives
After completing this chapter, you will be able to:
❒ Identify areas that should be inspected by a GTAW welder.
❒ Recall the various types of nondestructive tests and their advantages and disadvantages.
❒ Recall the various types of destructive tests.
❒ Recall the tests used in weld integrity inspections.
❒ Identify the conditions that require dimensional repairs and the techniques used to make these repairs.
❒ Identify various types of surface defects and explain corrective actions for each type.
❒ Recall procedures for finding and repairing internal defects.
❒ Recall the preparation needed prior to making repairs.
❒ Summarize proper welding practices for repairs.
❒ Explain the need for postweld inspection and repair review.

Key Terms
bend tests
corrosion tests
cross section tests
defect
destructive tests
discontinuity
dye penetrant test
fluoride test
flaw
fluorescent penetrant test
gamma rays
hardness tests
hydrostatic test
image quality indicator (IQI)
microtest
magnetic particle test (MT)
microhardness test
microtest
nick-break tests
nondestructive examination (NDE)
notch-toughness tests
penetrometers
penetrant test (PT)
pressure tests
quality control
radiographic test (RT)
temper beads
tensile tests
ultrasonic testing (UT)
visual test (VT)
X-rays

Introduction
Quality control is used throughout the welding industry to monitor the quality of the items produced. All manufactured items are made to specifications. Inspections must be made during and after the manufacturing cycle to ensure that parts meet the requirements of the specifications. The American Welding Society has increased the requirements for a CWI (certified welding inspector) certificate to ensure that certificate recipients are capable of performing quality control. Quality control is not only important to ensure quality parts but also to ensure that the correct procedures are performed as efficiently as possible. The use of proper quality control measures help make a company as strong as possible in an increasingly competitive industry.
Types of Inspection

Inspections are performed to determine whether a weld meets expectations. Depending on the final use of the weldment, several types of inspections may be required, ranging from simple visual inspection to rigorous testing.

Nondestructive Examination (NDE)

Inspections and tests of a weld that do not destroy any portion of the completed weld are called nondestructive examination (NDE). Inspections and tests that destroy the completed weld, or samples of the completed weld, are called destructive tests.

Visual Test

A visual test (VT) is one of the most important methods of inspection and is widely used for acceptance of welds. VT is also used to identify bad welds before other more expensive or time-consuming forms of inspection are performed. Visual inspection is easy to apply, quick, and relatively inexpensive. Visual testing equipment includes rulers, fillet weld gauges, squares, magnifying glasses, and reference weld samples. Some of the various tools used in weld inspection are shown in Figures 18-1, 18-2, and 18-3. These tools include the following:

- Optical Comparator. Magnifies, illuminates, and precisely measures weld discontinuities.
- Extension mirrors. Used for root pass inspection of pipe welds.
- Bridge cam gauge. Used for measuring several aspects of a weld, including the height.
- V-WAC gauge. Used for measuring height and depth. The gauge checks undercut depth, porosity comparison, amount of porosity per linear inch and crown height.
- Automatic weld size gauge. Measures several aspects of a weld, including the height.
- Fillet weld gauge. Measures the size of fillet welds.

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Penetrant Test

A penetrant test (PT) is a sensitive method of detecting and locating minute discontinuities that are open to the surface of the weld. A penetrating liquid (dye) is applied over the surface of the weld. The fluid then enters the discontinuity. After a short period of time, the excess penetrant is removed from the surface. A developer is applied to the surface and allowed to dry. The penetrant in the discontinuity rises to the surface by capillary action, making the discontinuity easy to see. The penetrant test sequence is shown in Figure 18-4.
A penetrant test is particularly useful on nonmagnetic materials, where a magnetic particle test cannot be used. Penetrant tests are used extensively for exposing surface defects in welds on aluminum, titanium, magnesium, and austenitic stainless steel weldments. Figure 18-5 shows how penetrant inspection can also be used to detect leaks in both open-top and sealed tanks or vessels. The penetrant is sprayed around all the weld areas. Penetrant works by capillary action and will identify any weld discontinuities or defects. When testing a sealed tank, the dye is sprayed (or brushed) on the external sides of the welds. The two types of penetrant tests are dye penetrant and fluorescent penetrant.

**A dye penetrant test** requires the surface of the weld to be sprayed generously with penetrant and allowed to soak for a specified time. Excessive penetrant is then removed with an aerosol cleaner. All of the penetrant is then wiped from the weld area. After the penetrant is removed, the developer is applied. The developer is a powdery white substance that is lightly applied from an aerosol can. Any imperfections in the weld will hold the dye and bleed through the white developer, identifying the problem. A dye penetrant test can be done anywhere because it is portable, and it can be done in any position. The results can be detected in normal light, without the use of special equipment.

**A fluorescent penetrant test** requires an ultraviolet light (black light) to observe the test results. It may be necessary to enclose the viewing area in order to properly read the test results.

**Magnetic Particle Test**

**A magnetic particle test (MT)** is a nondestructive method of detecting cracks, seams, inclusions, segregations, porosity, or lack of fusion in magnetic materials. This test can detect surface defects that are too fine to be seen with the naked eye or that lie slightly below the surface. When a magnetic field is established in a ferromagnetic material, minute poles are set up at any defects. These poles have a stronger attraction for magnetic particles than the surrounding material has. In a magnetic particle test, the ferromagnetic material is magnetized by an electric current, and iron particles or powder is applied to the magnetized area. If the magnetic field is interrupted by a defect, the iron particles form a pattern on the surface. The pattern is the approximate size of the defect. Figure 18-6 shows how magnetic particle tests are performed.

Small, portable, permanent magnets can be used for thin-gauge materials. Heavier material requires power from transformers, generators, or rectifiers. A typical magnetic particle unit is shown in Figure 18-7. The magnetic particle test can be performed using either the wet or the dry method, depending on the individual application. The wet method, in which the particles are suspended in a fluid, is generally more sensitive than the dry method. Wet magnetic particle inspection allows for a more even distribution of particles over a large area and is better for detecting very small discontinuities on a smooth surface. The dry method, which uses finely divided dry particles that are dusted onto a magnetized surface, is better for rough surfaces. Either red or gray particles can be used in the test. The color selected should provide good contrast with the material being tested.
The test can be modified by adding fluorescent dye to the particles. In this method, an ultraviolet light is used to illuminate fluorescent dye on the iron particles, allowing the inspector to clearly see and interpret the formation of the particles at the defect. As with fluorescent penetrant testing, it may be necessary to examine the weldment in a darkened area.

Accurate interpretation of magnetic particle tests requires training. Discontinuities revealed by the test pattern can be misleading to the untrained eye and may have no consequence on the weld’s acceptability. If the size of the discontinuity falls within allowable limits, the weld is still acceptable. If the size of the discontinuity is larger than the allowable limit, the weld is rejectable.

**Ultrasonic Test**

Ultrasonic testing (UT) is a nondestructive method of detecting the presence of internal cracks, inclusions, segregations, porosity, lack of fusion, and similar discontinuities in all types of metals. It can be used as the sole type of inspection, or it can be used with other types of testing. UT is often used in conjunction with radiographic testing because it determines the depth of the defect from the test surface.

In ultrasonic testing, very-high-frequency sound waves are transmitted through the part to be tested. The sound waves then return to the sender and are displayed as a graph on a monitoring screen for interpretation.

Since very-high-frequency sound waves travel only short distances in air, the test must be done with the part (signal sender) and the transducer (receiver) immersed in water or with the transducer coupled to the workpiece by a thin liquid film. These two methods are shown in Figure 18-8. UT inspection techniques include several different patterns and techniques. The technique used depends on the material, weld thickness, welding process, and inspection criteria being used. Where tests are required out-of-perpendicular with the transducer, a wedge or angle block is placed under the transducer at the desired angle to properly scan the material, as shown in Figure 18-9.

Ultrasonic testing is portable and nonhazardous. In addition, UT inspection has the following advantages:

- Great penetration power allows the testing of thick materials.
- High sensitivity allows detection of small discontinuities in a short period of time.
- Inspection can be done from one surface.

The major disadvantage of ultrasonic testing is the advanced skill required to properly interpret the results. Weld design, location of the defect, internal structure, and complexity of the weldment affect the interpretation of the ultrasonic signal.

In order to achieve the desired results, calibration blocks and reference weld samples are used to calibrate the equipment prior to making the test. With the proper calibration, the operator can then interpret the results to the inspection specification.

**Radiographic Test**

A radiographic test (RT) is a nondestructive method that reveals the presence and nature of discontinuities in the interior of welds. This test makes use of the ability of short wavelength radiations, such as X-rays or gamma rays, to penetrate material that is opaque to ordinary light.

X-rays are a form of electromagnetic radiation that penetrates most materials. An X-ray test is similar to a photograph. A machine in a fixed location transmits X-rays through the material being tested. A film or sensor on the other side of the material is exposed by the X-rays that pass through the test material. Any defects or inconsistencies in the metal change the amount of X-rays that are able to pass through. Because more or fewer X-rays pass through these locations, they look different in the developed film, or display.

The area surrounding the X-ray machine may be lead-shielded to prevent the escape of radioactive activity. An X-ray testing station usually includes all of the support equipment, such as film-developing machines. The end result is a radiograph made in a minimum amount of time. Recently, more portable X-ray equipment has been developed and is becoming very common in the pipeline industry. This equipment consists of a small machine that is sent down the center of the pipe to X-ray each weld. Gamma rays are electromagnetic waves that are similar to X-rays, but with a shorter wavelength. Gamma rays are produced from radioactive materials such as cobalt, cesium, iridium, and radium. These radioactive materials must be contained in a lead-shielded box and transported to the job site for in-place radiographs.

The film that is exposed by these rays is called a radiograph. Film is placed on one side of the weld, and the radiation source is placed on the other side of the weld. The radiation passes through the test material and exposes the film, revealing any inconsistencies in the weld. Different types of radiation sources are more or less powerful. The thickness of the material usually determines the type of radiation source used for the test.

A radiograph inspection of a fusion weld is shown in Figure 18-10. The film is developed for viewing on a special viewer. The radiograph must be compared by a skilled technician to a specification that defines discontinuities. The film must have sharp contrast for proper definition of the weld and identification of any defects. (Contrast is the degree of blackness of the darker areas compared with the degree of lightness of the brighter areas.)

To ensure sharp images on the film, image quality indicators (IQI), also called penetrameters, are used to indicate the quality of the radiograph. A hole-type penetrameter consists of a thin shim of the base metal, usually with a thickness equal to 2% of the weld thickness. One, two, or more holes with various diameters are drilled into the metal shim. The shim is laid next to the weld before being X-rayed. The ability of the radiograph to show definite-sized holes in the penetrameter establishes the radiograph quality. The resolution of the X-ray is indicated by the smallest hole that is visible.

Another type of IQI is a wire type. A wire IQI is a series of wires embedded in plastic. The wires have decreasing diameters. The quality of the radiograph is determined by the thinnest diameter wire that can be seen on the image. Figure 18-11 shows a wire-type IQI.

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the weldment has been in service. This comparison can help engineers identify areas of the weldment that are stressed by service.

Destructive Tests

Destructive tests are used for welder qualification and certification, as well as welding procedure qualifications. In large production runs, destructive tests are often made by pulling apart sample units. It is often less expensive to scrap a part to make a destructive quality test than to test the parts using more expensive nondestructive tests.

Bend Test

Bend tests are used to determine internal weld quality. As shown in Figure 18-12, there are three different types of bend tests:

- face bend (face of the weld is tested)
- root bend (root of the weld is tested)
- side bend (sides of the weld are tested)

In bend tests, a weldment is sliced into test strips, called coupons. The weld is then bent around a die of a specific size, creating a horseshoe of the coupon. This process stretches the weld to test the weld’s integrity.

Figure 18-13 shows a radius bend testing machine. This machine bends the prepared test coupon into a U form over a specified radius, which is dependent on the thickness and strength of the material. After bending, the outer surface and the inner surface of the U are checked for cracks and other indications as required by the weld inspection criteria. The outer face of the bend may be examined by a visual, penetrant, or magnetic particle test to detect defects such as cracks, lack of fusion, and lack of penetration.

Tensile Test

Tensile tests are used to compare the weldment to the base metal mechanical values and specification requirements. The weldment is sliced into coupons, and then each end of the coupon is pulled in opposite directions until the coupon fails (breaks). A tensile test machine is shown in Figure 18-14.

Tensile tests are made to determine the following:

- Ultimate strength of the weld. This is the point at which the weld fails under tension.
- Yield strength of the weld. This is the point at which the weld yields or stretches under tension and will not return to its original dimensions.
- Elongation. This is the amount of stretch that occurs during the tensile test. It is measured by placing gauge marks on the sample or coupon before testing and comparing the after-break distance with the original gauge marks.

Figure 18-12. The three types of bend tests are shown here. The root bend test places the greatest amount of stress on the weld root. The face bend test places the greatest amount of stress on the weld face. The side bend places the greatest amount of stress along the weld axis.

Figure 18-13. A radius bend testing machine. (Mark Prosser)

Figure 18-14. This tensile test machine has a recorder mounted on the side to record the test operation parameters and results. A tensile test machine can be equipped with fixtures for holding weld coupons for testing. (Photo courtesy of Tinius Olsen)

Figure 18-15. Charpy and Izod test bar dimensions.

Notch-Toughness Test

Notch-toughness tests are used to define the ability of welds to resist cracking or crack propagation at low temperatures under loads. These tests are used on welds that are intended for use in low temperature environments with pulsating or vibrating loading. The weldment is cut into test coupons, which are then notched, cooled to a low temperature, and put under pressure until they fail.

The test coupons are cut from the test weld. They are prepared for either a Charpy or an Izod impact test, Figure 18-15. The test bars are cooled to the test temperature and then placed into the test machine and broken, Figure 18-16. The results are measured in the energy required to make the coupon break and are expressed in foot-pounds. Comparisons are then made with the original material and specification requirements.

Cross Section Test

Cross section tests are used to define the internal quality and structure of the weld. The weldment is cut...
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into cross sections, which are then polished, etched, and examined visually or with specialized testing equipment. Cross section tests include the following types:

- **Macrotensile Test**. Polished sections of the weld are prepared for viewing with the naked eye or a magnifying glass (low magnification). Increased definition of the weld layers and passes can often be obtained by etching the sample with a suitable etchant.

- **Microtensile Test**. Very highly polished sections of the weld are prepared for viewing with high-power microscopes. This type of test is used to determine grain size, content, and structure.

- **Microhardness Test**. Very highly polished sections of the weld are tested on special machines to determine the hardness of a very small area. The test results can then be evaluated to determine the hardness variations within the grain structures and the weld zones.

**Nick-Break Test**

Nick-break tests are destructive tests that are very simple to make. They are used to determine the internal quality of a weld with regard to porosity, lack of fusion, and slag. Notches are cut in the sides of a weld coupon in the weld area. The coupons are then laid across a support on each end and force is applied with a hammer to try to break the weld sideways for a simple internal inspection. A nick or groove cut into the weld helps the specimen break when force is applied.

A section of the weld to be tested is removed from the weld and prepared as shown in Figure 18-17. The coupon is then placed into a vise, Figure 18-18, and broken with a sharp blow to the upper section. Defects can then be observed in the broken areas.

**Pressure Test**

Pressure tests subject a vessel, tank, piping, or tubing to internal pressure. Pressure tests can use either air or fluid. If a fluid is used, the test is called a hydrostatic test. The test program may require a number of cycles to be performed, simulating the use of the part in actual service. During the test, the part will expand. This expansion should not be restricted with tools, or undue stresses will build within the part.

When conducting a pressure test, be alert to the possible failure of the unit. Before beginning the test, make sure the test procedure ensures the safety of everyone in the testing area.

**Hardness Test**

Hardness tests involve pressing a test probe into the surface of the weld. The amount of pressure required to deform the surface of the weld metal is an indication of the hardness of the weld or weldment. If the weldment has been heat-treated (annealed, hardened, tempered, etc.) after fabrication, the hardness test will determine the effect of the heat treatment. A hardness tester is shown in Figure 18-19.

Hardness test results can also be used to determine the ultimate tensile strength of the material. The test results can be compared with standard tables. (Refer to the hardness conversion table included in the reference section of this book.) Weldment designs that include areas such as flanges and extensions can be tested by portable hardness testers as shown in Figure 18-20.

Weldment designs that do not have clear areas for testing must have test bars of the same material (welds if required) submitted with the weldment during the heat-treating cycle. The bars are then tested on a stationary tensile machine, as shown in Figure 18-24, for the hardness results. Round tensile test bars are shown in front of the tester in Figure 18-21. A flat tensile test bar is being tested in Figure 18-21.

**Corrosion Test**

Corrosion tests measure the ability of a weld to restrict corrosion by a specific material. These tests are usually performed on test weldments. The test...
parts are sprayed with a salt mixture and allowed to corrode, simulating years of exposure to the weather. Such tests are usually required by the specification used by the fabricator. Weld test parameters and filler metals used on qualification test weldments must be duplicated on the production part without deviation to maintain the proper ferrite content.

**Weld Repair**

If a weldment fails inspection, the welding inspector will review it in order to determine the extent of damage that may be caused by repairing the weld and whether the weldment can fulfill its function if the defect is allowed to remain in place. If the function of the weldment is affected by the defect, the weldment must be discarded and replaced. In some cases, the defect may not affect the functionality of the weldment, in which case it can be left. These determinations are made on a case-by-case basis.

If a part requires rework, a thorough welding procedure should be established to minimize the effect of the repair on the remaining portion of the weld. This procedure must consider the procedure used to create the original weld. It must also consider the following:

- the condition of the base metal and weld
- the type of filler metal to be used in the repair
- the welding sequence
- any in-process inspection required during the repair
- tooling required for the repair
- the final weld’s mechanical properties

Incomplete consideration of any of these factors may result in further rejection of the weld repair and possible failure of the weld when placed into service.

**Dimensional Repairs**

Dimensional repairs are repairs that are required because the weld is too small for the material and joint type. These repairs involve the addition of material to increase weld size and are usually necessary due to the insufficient addition of filler metal during the welding operation. Conditions that require dimensional repairs are as follows:

- Crown height is too low, Figure 18-23. A low crown does not provide adequate reinforcement of the weld. Repair this type of defect with stringer beads to minimize weld shrinkage. Add only enough new filler metal to build the crown to height requirements. Do not overweld.
- Surfacing or overlay type weld height is too low, Figure 18-24. Surfacing or overlay that is not high enough reduces the durability and service life of the surfaced material. Repair this type of defect with stringer beads to minimize dilution and distortion.
- Fillet weld size is too small, Figure 18-25. A small fillet weld does not provide adequate strength in the joint. The weld is repaired by removing the inadequate weld and rewelding to create the proper size fillet weld.

Regardless of the repair technique, these repairs require close control to avoid overwelding and adding additional stress to the original weld.

**Surface Defect Repairs**

Defects seen on the surface of the weld can extend deep into the weld. For this reason, the defect must be removed. After the defect has been removed, the area must be reinspected before a repair can be attempted. Common defects and factors to be considered when repairing them are as follows:

- Longitudinal, transverse, or crater cracks, Figure 18-26. On steel and steel alloys, use a small grinding wheel like the one shown in Figure 18-27 to remove cracks. Remove only the amount of metal required to eliminate the crack.

Regardless of the repair technique, these repairs require close control to avoid overwelding and adding additional stress to the original weld.
For all other types of metal, use small rotary tungsten carbide tools to remove the crack. Do not use grinding wheels on nonferrous material. When repairing, add only sufficient filler metal to match the adjacent weld contour.

- **Undercut**: at the edges of the weld, Figure 18-28. Dirt, scale, and oxides may be present in the undercut area. These impurities can cause further defects if not removed prior to weld repair. Remove these impurities by grinding or routing as previously described. Be careful not to remove base metal adjacent to the undercut. Since the repair will widen the original crown size, use lower currents and sufficient wire to prevent additional undercuts and underfill.

- **Porosity**: or pores in the weld, Figure 18-29. Remove isolated or single pores with a rotary tool for weld repair. Remove multiple and linear (aligned in a row) pores by grinding or machining. Then reinspect the weld by radiographic or ultrasonic inspection to ensure that the porosity has been completely removed before repairs are started. For weld repair, always fill the deepest part of the recessed area first. Keep each layer of weld level until the area is filled.

- **Cold laps**: Figure 18-30. are areas of the weld that have not fused with the base metal. Cold laps can occur on fillet welds or butt welds, usually as a result of a travel speed that is too slow. Since the extent of the overlap cannot be determined by NDT, remove the entire area by grinding or routing. Use extreme care when grinding into lap joints to prevent grinding into adjacent metal and creating more problems. When the overlap material has been removed, perform a penetrant test to determine if the defect is entirely gone. Continue removing material until the penetrant test is satisfactory. If weld repair is required to satisfy crown height requirements, use low currents and sufficient wire to match the crown with adjoining material.

- **Incomplete penetration**: on the root side of butt welds. Other types of defects can also occur on the root side of the weld, such as concave root surface, cracks, porosity, melt-through, etc. See Figure 18-31. Remove all of these areas by grinding or routing. To ensure complete removal of all defects, perform a penetrant test before rewelding. Since oxides form in this area during welding, clean the repair area to bright metal before rewelding. Use stringer beads and add only enough wire to build a small crown.

### Internal Defect Repairs

Internal defects, Figure 18-32, may or may not extend to the surface and might not be found by surface inspection. They are generally found by radiographic and ultrasonic testing. Once the defect has
been located by a radiographic test, the defect can be marked on the X-ray film. The film is aligned over the weld, and a punch can be used to indent the area over the defect. The film is then removed, and the indent can be located by a penetrant test. The indent is then removed, and the area is thoroughly cleaned.

Finding the defect in the weld by grinding or routing requires both skill and patience. Porosity and large areas exhibiting lack of fusion are generally easy to locate and remove. Cracks and small areas with incomplete fusion are more difficult to locate.

The following is a suggested procedure for repairing an internal defect in a groove weld:

1. If the defect depth is known, remove metal to within approximately 1/16 in. (1.6 mm) from the defect. During the metal-removal process, use a magnifying glass to inspect the ground area. If the crack is in the right plane, a light blue surface will sometimes be found at the edge of the crack. This is caused by overheating of the crack edge. This is also a good situation for a dye penetrant test.

2. Perform a penetrant test on the grooved area. If no indication of a crack or defect is seen, remove the penetrant.

3. Grind .010–.015 in. (.25 mm–.38 mm) deeper.

4. Penetrant test the grooved area again. Continue penetrant testing, grinding, and retesting until the defect is found.

5. If the defect is still not found, X-ray to determine if the defect remains. If the crack is not found after removing metal halfway through the part, reweld the ground area. Then work from the opposite surface to remove the crack. Never grind a slot or a hole through the part. Repairing a slot causes excessive distortion in the adjacent areas or shrinkage and the possibility of more defects. The removal of defects in fillet welds is difficult due to limited access of the grinder. If the penetrant is allowed to penetrate into the joint, it can cause many problems during weld repair. For a fillet weld, it is easier to use visual inspection or radiographic tests to ensure that the defect has been removed.

Preparing for Repair
After the defect is removed, prepare the area for welding by removing all rough edges on the ground area. Any oil, grease, scale, or penetrant residue must be removed with alcohol or acetone. Do not use grit blasting in the grooved area. Grit material can become embedded in the ground area and become trapped in the weld repair.

Welding for Repairs
- If possible, use stringer beads with minimum amperage for minimum shrinkage of the joint.
- Whenever possible, use a current-tapering (crater fill) control on amperage to prevent crater cracks.
- Clean scale and oxides from each weld pass.
- Visually inspect each weld pass after cleaning.
- If the weld repair is deep, have an X-ray made after two or three completed passes to confirm that new cracks have not formed. This should also be done if there is any doubt about removal of the original crack.
- Always use a backing gas if the root of the weld may be exposed to air.
- Where possible, use the original parameters for preheat, interpass temperature, and postheat.
- Do not build the repair crown any higher than is required. Each pass that is made stresses the base of the weld due to shrinkage.
- When the grain size must be controlled throughout the repair, weld temper beads on top of the weld, as shown in Figure 18-33. These beads reduce the surface grain size and are removed after welding.

Figure 18-33. Temper beads are used to obtain an even structure throughout the top area of the weld. Since they add significant height to the crown, they are usually removed after welding.

Postweld Inspection
All of the nondestructive testing (NDT) required for final acceptance of the weld must be completed after the weld repair is done. This means that even if several inspections were satisfactory before the weld was rejected, all of the inspections must be redone. Repairs can cause new problems in a weld. After a repair is made, the entire weldment must be reinspected.

Repair Review
Repairs are expensive and often detract from the appearance of the final weld. Everything within reason should be done to eliminate defects that require costly repairs. Review every flaw and defect in the weld, regardless of its severity, to determine its cause. Plan the possible corrective action that can be taken in the future to eliminate similar problems.

Repair review should include the following areas:
- base material
- tooling
- preparation for welding
- joint preparation
- process application (welding variables)
- welder training and skill
Summary
Inspections are made during and after the manufacturing cycle to ensure that parts meet specifications. Types of inspection include nondestructive examination (NDE), in which no portion of the completed weld is destroyed, and destructive tests, in which the weld is destroyed. Weld integrity inspections may also be required in addition to the nondestructive test requirements to verify the weld quality. NDE includes visual tests, penetrant tests, magnetic particle tests, ultrasone tests, and radiographic tests. Destructive tests include bend tests, tensile tests, notch-toughness tests, cross section tests, and nick-break tests. Weld integrity inspections include pressure tests, hardness tests, corrosion tests, and ferrite tests.

Intended weld repairs must be evaluated as to whether the discontinuity should be removed. Repairing a completed weld could cause buckling, distortion, or misalignment of the reworked area. In some cases, a discontinuity can be left in a weld without affecting the weld’s function. Repairs can be made to correct dimensional problems, surface defects, and internal defects. Common surface defects include longitudinal, transverse, or crater cracks; undercut at the edges of the weld; porosity; cold laps; and incomplete penetration. Internal defects are generally found by radiographic and ultrasonic testing.

Stringer beads should be used for welding repairs in order to minimize shrinkage of the joint. If the weld repair is deep, an X-ray should be made after two or three completed passes to confirm that the original crack has been fully repaired and new cracks have not formed. Where the grain size must be controlled throughout the repair, temper beads should be used to reduce the surface grain size.

All nondestructive testing required for final acceptance of the weld must be completed after the weld repair is done. Repairs can cause new problems in a weld.

Review Questions
Write your answers on a separate sheet of paper. Do not write in this book.

1. Inspections and tests made on a weld that do not destroy any portion of the completed weld are called _____.
2. A(n) _____ test is used to identify bad welds before other more expensive and time-consuming types of inspection are performed.
3. What is the difference between a flaw and a defect?
4. A penetrant test (PT) will only reveal discontinuities that are located _____.
5. In a magnetic particle test, _____ particles form a pattern on the surface of the material where a defect is located.
6. What does an ultrasonic test of a weld reveal?
7. List four factors that can cause misinterpretation of an ultrasonic test.
8. Radiographic tests use the ability of short wavelength radiations, such as _____ or _____, to penetrate opaque material.
9. What is the purpose of a penetrameter?
10. List the three types of bend tests.
11. List the three mechanical values of a weld determined by tensile tests.
12. _____ tests are used to define the ability of welds to resist cracking or crack propagation at low temperatures under loads.
13. A pressure test that uses fluid is called a(n) _____ test.
14. In a corrosion test, test weldments are sprayed with a(n) _____ mixture and allowed to corrode.
15. Why should all rejected welds be thoroughly reviewed before attempting a repair?
16. List three conditions that require dimensional repair.
17. What should be avoided when grinding out undercut defects?
18. What type of defects located in the body of a weld are very hard to locate using grinding or routing?
19. What should be done when making a deep weld repair to confirm that new cracks have not formed?
20. _____ beads reduce the surface grain size and are removed after welding.