



PV Newsletter

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NONDESTRUCTIVE METHODS OF EXAMINATION

Definitions

Nondestructive Examination: Nondestructive examination is a general term used to identify the common inspection method for evaluation of welds and related materials without destroying their usefulness.

Discontinuity: It is an interruption of the typical structure of the material, such as a lack of homogeneity in the mechanical, metallurgical or physical characteristics. Discontinuity is a defect when it exceeds the sizes and types of discontinuities defined as rejectable by the applicable specification.

Examination Method Selection Guide

Visual Examination (VT):

Applications: Weldments that have discontinuities only on the surface

Advantages: The method is economical and expedient, and requires relative little training and relatively little equipment for many applications.

Limitations: The method is limited to external or surface conditions only and by the visual acuity of the inspector

Liquid Penetrant (PT):

Applications: Weldments that have discontinuities only on the surface

Advantages: The equipment is portable and relatively inexpensive. The inspection results are expedient and easily interpretable. This method requires no electrical energy except for light sources.

Limitations: Surface films such as coatings, scale, and smeared metal may mask or hide discontinuities. Bleed out from porous surfaces can also mask indications. Parts must be cleaned before and after inspection.

Magnetic Particle (MT):

Applications: Weldments that have discontinuities on or near the surface.

Advantages: The method is relatively economical and expedient. Inspection equipment is considered portable. Unlike dye penetrants, magnetic particles can detect some discontinuities slightly below the surface.

Limitations: The method is applicable only to ferromagnetic materials. Parts must be cleaned before and after inspection. Thick coatings may mask rejectable discontinuities. Some applications require the part to be demagnetized after inspection. MT requires use of electrical energy for most applications.

Radiography - Gamma (RT Gamma):

Applications: Weldments that have voluminous discontinuities such as porosity, incomplete joint penetration, slag, etc. Lamellar type discontinuities such as crack and incomplete fusion can be detected with a lesser degree of reliability. It may also be used in certain applications to evaluate dimensional requirements such as fit-up, root conditions and wall thickness.

Advantages: The method is generally not restricted by the type of material or grain structure. The method detects surface and sub-surface discontinuities. Radiographic images aid in characterizing discontinuities. The film provides a permanent record for future review.

Limitations: Planar discontinuities must be favorably aligned with radiation beam to be reliably detected. Radiation poses a potential hazard to the personnel. Cost of radiographic equipment, facilities, safety programs and related licensing is relatively high. There is a relatively long time between exposure process and availability of results. Accessibility to both sides of weld is required.

Radiography – X Rays (RT X Rays):

Applications: Same as that for Gamma radiation.

Advantages: Same as for gamma radiation except x-ray radiography can use adjustable energy levels and it generally produces higher quality radiographs than gamma sources.

Limitations: Initial cost of x-ray equipment is high. This method is not generally considered portable. Additionally, all the limitations for Gamma Radiation apply.

Ultrasonic (UT):

Applications: This method can detect most weld discontinuities including cracks, slag, and incomplete fusion. It can also be used to verify base metal thickness.

Advantages: The method is most sensitive to planar type discontinuities. The test results are known immediately. The method is portable and most UT flaw detectors are battery operated. The method has high penetration capability.

Limitations: Surface condition must be suitable for coupling of transducer. A liquid couplant is required. Small thin welds may be difficult to inspect. Reference standards and a relatively skilled operator or inspector are required.

Costs

Costs of various inspection methods depend on the particular situation. Two factors that should be considered in the selection of a NDE method are that of the equipment and of performing the inspection. Visual examination is usually the least expensive but it is limited to the detection of surface discontinuities. In general, the cost of RT and UT is higher than that of VT, PT or MT. To meet the intended purpose and to minimize the costs, a qualified engineer should be consulted.

Discontinuities

Discontinuities may be found in the weld metal, heat affected zones, and base metal of weldments made in the five basic weld joint types: butt, T-, corner, lap and edge joints. A partial list of discontinuities that may be encountered in the fabrication of metals by welding are discussed here. When specific discontinuities are located in the weld metal, heat-affected zone, or base metal, the abbreviations WM, HAZ, and BM, respectively, are used to indicate the location.

The most common types of discontinuities are listed in the Table 1 and depicted in the Figures 1 through 10. Where the list indicates that the discontinuity is generally located in the weld, it may be expected to appear in almost any type of weld. Tungsten inclusions are an exception – they are found only in the welds made by gas tungsten arc or plasma arc welding processes. The location WI refers to the weld interface.

Table 1: Common Types of Discontinuities

Type of Discontinuity	Location	Remarks
1) Porosity	WM	Porosity can also be found in BM and HAZ if base metal is a casting
2) Inclusion	WM, WI	
3) Incomplete Fusion	WM, WI	WM between passes
4) Incomplete Joint Penetration	BM	Weld root
5) Undercut	WI	Adjacent to weld toe or weld root in base metal
6) Underfill	WM	Weld face or root surface of a groove weld
7) Overlap	WI	Weld toe or root surface
8) Lamination	BM	Generally near midsection of thickness
9) Delamination	BM	Generally near midsection of thickness
10) Seam and Lap	BM	Base metal surface generally aligned with rolling direction
11) Lamellar tear	BM	Near HAZ
12) Cracks	WM, WI, BM, HAZ	Weld metal or base metal adjacent to WI
		Weld metal (may propagate into HAZ and base metal)
		Weld metal at point where arc is terminated
		Parallel to weld axis through the throat of fillet weld
		Root surface or weld root
13) Concavity	BM	Weld face of fillet weld
14) Convexity	BM	Weld face of fillet weld
15) Weld reinforcement	BM	Weld face of groove weld

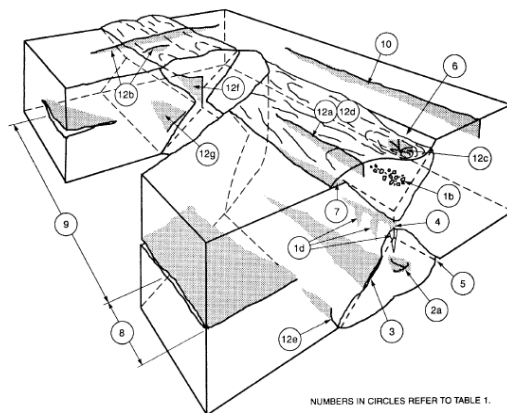
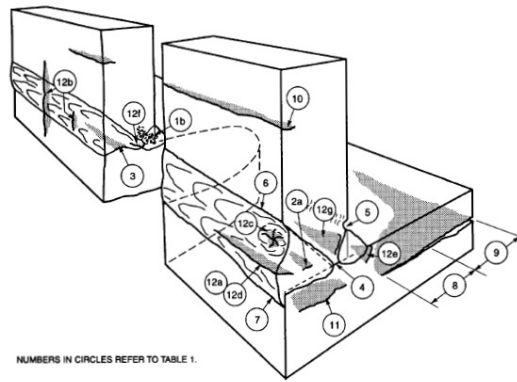
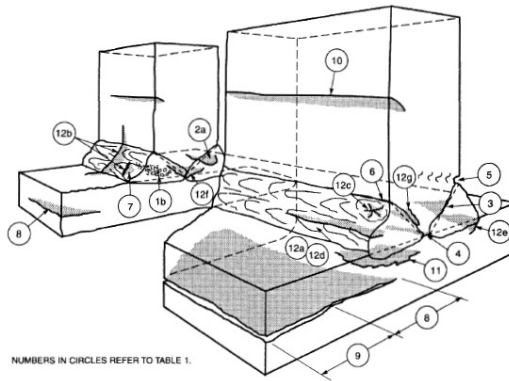


Figure 1: Double V-Groove Weld in Butt Joint



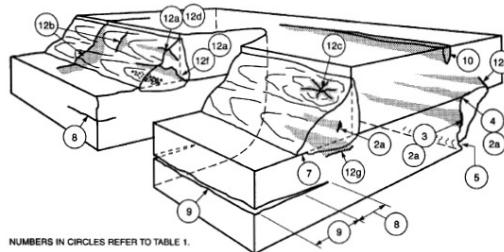
NUMBERS IN CIRCLES REFER TO TABLE 1.

Figure 2: Single Bevel Groove and Fillet Welds in Corner Joint



NUMBERS IN CIRCLES REFER TO TABLE 1.

Figure 3: Double Bevel Groove Weld in T-Joint



NUMBERS IN CIRCLES REFER TO TABLE 1.

Figure 4: Double Fillet Weld in Lap Joint

Porosity

Porosity can be of five kinds. *Scattered Porosity* (1a in Figures) is uniformly distributed throughout the weld metal. The cause is generally faulty welding technique or materials. The joint preparation techniques or materials may also result in conditions that cause scattered porosity. If a weld solidifies slowly enough to allow most of the gas to pass to the surface before weld solidification, there will be few pores in the weld. *Cluster Porosity* (1b in Figures) is a localized array of porosities having a random geometric distribution. It often results from problems in initiation or termination of a weld pass. *Piping Porosity* (1c in Figures), also known as *Wormhole Porosity*, is a form of porosity having a length greater than its width that lies approximately perpendicular to the weld face. Piping porosity in fillet welds extends from the weld root to the weld surface. Much of the piping porosity found in welds does not extend all the way to the surface. Careful excavation may also reveal subsurface porosity. *Aligned Porosity* (1d in Figures), also known as *Linear Porosity*, is a localized array of porosity oriented in a line. The pores may be spherical or elongated. It often occurs along a weld interface, the interface of weld beads, or near the weld root, and is caused by

contamination that leads to gas evolutions at these locations. *Elongated Porosity* (1e in Figures) is a form of porosity having a length greater than its width that lies approximately parallel to the weld axis.

Inclusions

Inclusions are entrapped foreign solid materials. *Slag Inclusions* (2a in Figures) are discontinuities resulting from the entrapment of nonmetallic products within the weld metal. Slag inclusions result from mutual dissolution of flux and nonmetallic impurities in some welding or brazing processes. They can be found in welds made with any arc welding process that employs flux as a shielding medium. In general slag inclusions result from improper welding techniques, the lack of adequate access for welding the joint, or improper cleaning of the weld between passes. Due to its relatively low density and melting point, molten slag will normally flow to the surface of the weld pass. Sharp notches in the weld interface or between passes often cause slag to be entrapped under the molten weld metal. The release of slag from the molten metal will be expedited by any factor that tends to make the metal less viscous or retard its solidification, such as high heat input.

Tungsten Inclusions (2b in Figures) are tungsten particles trapped in the weld metal. Tungsten inclusions are often associated with the gas tungsten arc welding process and are sometimes associated with the plasma arc welding process. Tungsten inclusions appear as light indications on radiographs because tungsten is denser than steel or aluminum and absorbs more of the radiation.

Incomplete Fusion

This is a weld discontinuity in which fusion does not occur between weld metal and fusion faces or adjoining weld beads. It is a result of improper welding techniques, improper preparation of base metal, or improper joint design. Deficiencies causing incomplete fusion include insufficient welding heat or lack of access to all fusion faces, or both. Unless the weld joint is properly cleaned, the tightly adhering oxides can interfere with complete fusion, even when there is proper access for welding and proper welding heats are used.

Incomplete Joint Penetration

This is a joint root condition in which the weld metal does not extend through the joint thickness. The unpenetrated and un-fused area is a discontinuity described as incomplete joint penetration. It may result from insufficient welding heat, improper joint design, or improper lateral control of the welding arc.

Some welding processes have much greater penetrating ability than others. For joints welded from both sides, backgouging may be specified before welding the other side to ensure that there is no incomplete joint penetration. Pipe welds are especially vulnerable to this type of discontinuity since the inside of the pipe is usually inaccessible. Designers may employ a backing ring or consumable inserts to aid welders in such cases. Welds that are required to have complete joint penetration may require examination by visual or some other NDE method.

Undercut

Undercut is a groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by the weld metal. This groove creates a mechanical notch which is a stress concentrator. When undercut is controlled within the limits of specifications it is not considered a weld defect. Undercut is generally associated with either improper welding techniques or excessive welding currents, or both.

Underfill

It is a condition in which the weld face or root surface of a groove weld extends below the adjacent surface of base metal. It results from the failure of the welder to completely fill the weld joint.

Lamination

Lamination is a type of base metal discontinuity with separation or weakness generally aligned parallel to the worked surface of a rolled product. Laminations may be completely internal and are usually detected nondestructively by UT. They may also extend to an edge or end, where they are visible at the surface, and may be detected by visual, PT or MT method. They may be found when cutting or machining exposes internal laminations.

Laminations are formed when gas voids, shrinkage cavities, or nonmetallic inclusions in the original ingot are rolled flat. They generally run parallel to the surface of rolled products and are most commonly found in shapes and plates. Metals containing laminations cannot be relied upon to carry tensile stress in the through thickness direction.

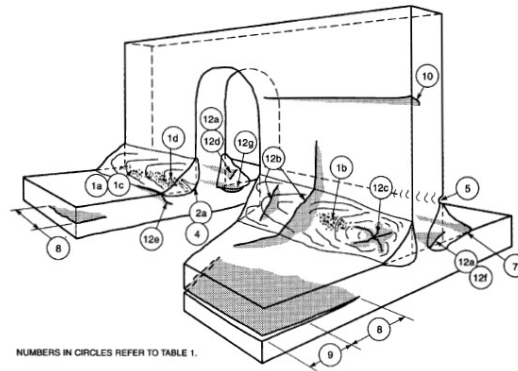


Figure 5: Single Pass Double Fillet Weld in T-Joint

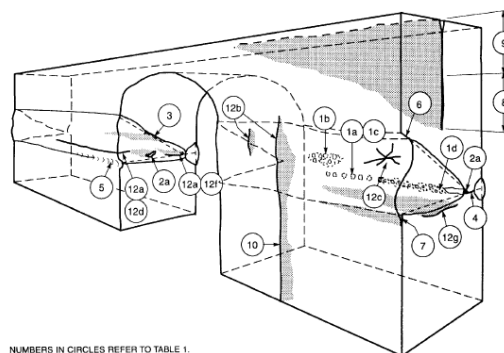


Figure 6: Single Bevel Groove Weld in Butt Joint

Delamination

It is a lamination that has separated under stress.

Seams or Laps

These are base metal discontinuities that may be found in rolled, drawn or forged products. They differ from lamination in that they appear on surface of the worked product. When the discontinuity is parallel to the principal stress, it is not generally a critical defect. When seam and laps are perpendicular to the applied or residual stresses, they will often propagate as cracks. While seams and laps are surface discontinuities, their presence may be masked by manufacturing processes that have subsequently modified the surface of the mill product. Welding over seams and laps can cause cracking or porosity.

Lamellar Tear

It is a subsurface terraced or step-like crack in the base metal with a basic orientation parallel to the wrought surface. It is caused by tensile stresses in the through thickness direction of the base metals weakened by the presence of small, dispersed, planar shaped, nonmetallic inclusions which are parallel to the metal surface. Lamellar tearing often occurs in heavy section materials.

Lamellar tearing may extend over long distances and generally initiates in regions of base metals that have a high incidence of stringer-like, nonmetallic inclusions in parallel planes and high residual stresses. The fracture usually propagates from one lamellar plane to another by shear lines that are near normal to the rolled surface.

Cracks

Cracks are defined as fracture type discontinuities characterized by a sharp tip and high ratio of length and width to opening displacement. They can occur in the weld metal zone, heat affected zone, and base metal when localized stresses exceed the ultimate strength of the material. Cracking often initiates at stress concentrations caused by other discontinuities or near mechanical notches associated with the weldment design. Stresses that cause cracking may be either residual or applied. Residual stresses develop as a result of restraint provided by weld joint and thermal contraction of the weld following solidification. Welding related cracks are generally brittle in nature, exhibiting little plastic deformation at the crack boundaries.

A crack formed in the first layer of a weld and not completely removed before the next layer is deposited tends to progress into the layer above and then each succeeding layer until finally it may appear at the surface. The final extension to the surface may occur during cooling after welding has been completed.

Concavity

Concavity is the maximum distance from the face of a concave fillet weld to a line joining the weld toes. It is sometimes called insufficient throat. Concavity is not rejectable unless the weld is undersize. Concave fillet welds must be inspected by using a fillet weld gauge capable of measuring the throat dimension, since that is the limiting dimension in terms of the size of a concave fillet weld. A concave profile fillet weld size cannot be correctly measured by the leg size.

Convexity

Convexity is the maximum distance from the face of a convex fillet weld to a line joining the weld toes. The convexity results in a mechanical notch at the junction of the weld face and the base metal similar to that produced by overlap. The severity is greater when the convexity is greater.

Weld Reinforcement

In groove welds, weld reinforcement is weld metal in excess of the quantity required to fill a joint. Weld reinforcement may be located at both the root and the face of a groove weld. Weld reinforcement is undesirable when it creates high stress concentrations at the weld toes or weld root similar to convexity. It tends to establish notches that create stress concentrations. This condition may result from improper welding technique or insufficient welding current.

Nondestructive Examination Methods

NDE is a general term used to identify all methods that permit evaluation of welds and adjacent areas without destroying their usefulness. Here the following basic NDE methods will be discussed:

- 1) Visual
- 2) Penetrant
- 3) Magnetic particle
- 4) Radiographic
- 5) Ultrasonic

It should be noted that NDE does not eliminate the need for destructive testing but rather complements it. The general knowledge presented here should be of valuable assistance to the reader as it provides an overview of the examination methods without unnecessary details.

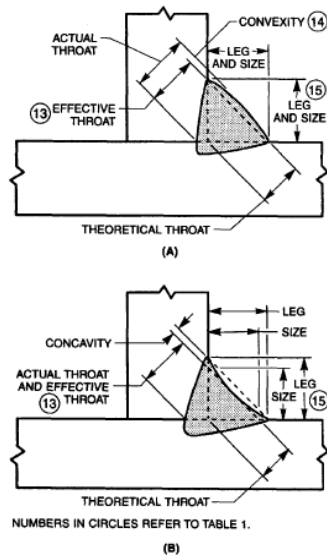


Figure 7: Fillet Weld Terminology

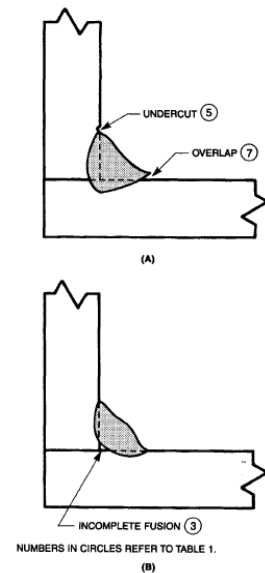


Figure 8: Fillet Weld Discontinuities

Visual Examination (VT)

The integrity of most welds is verified principally by visual examination. Even for weldments with joint specified for inspection throughout by other NDE methods, VT still constitutes an important part of practical quality control. The most extensively used of any method of NDE, VT is easy to apply, quick, and often requires no special equipment other than good eyesight and some relative simple and inexpensive tools.

Despite the many advantages of VT, a major disadvantage is the need for an inspector who has considerable experience and knowledge in many different areas which encompass visual welding examination. The inspector must be familiar with materials, drawings, codes, specifications, weld procedures, performance qualification, procedure qualification requirements, and workmanship standards, and all aspects of good shop practice. Some codes and specifications require that the welding inspector be qualified and certified by examination.

Certain tools are sometimes necessary for some aspects of VT. Various measuring scales and gauges are used for checking the dimensions of the welds. There are many different types of fillet weld gauges used to determine the size of fillet welds. Other gauges can be used to verify root opening, weld reinforcement, and weld bevel angle. Measuring devices are used to check root openings, clearance dimensions of materials, backing materials, and alignment and fit-up of the work pieces. Temperature indicators verify preheat and interpass temperatures. Borescopes, videoscopes, flashlights and mirrors are used in areas of limited accessibility. The development of flexible fiberoptic inspection systems enables the inspector to visually inspect areas inaccessible to other devices.

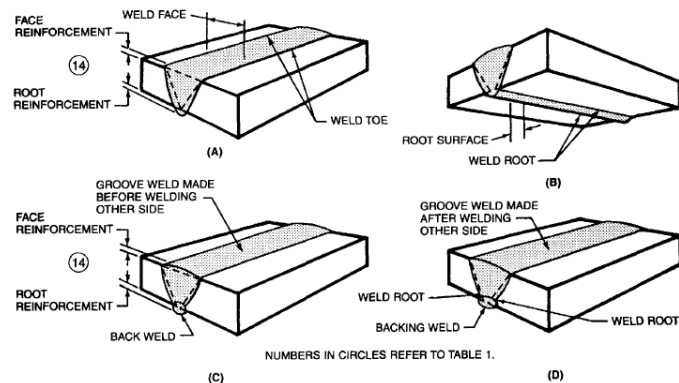


Figure 9: Groove Weld Terminology

Liquid Penetrant Examination (PT)

PT is a sensitive method of detecting and locating discontinuities, provided the discontinuities are clear and open to the surface. The method employs a penetrating liquid dye which is applied to the properly cleaned surface to be examined and which enters the discontinuity. After a suitable dwell time, the excess penetrant is removed from the surface and the part is dried. A developer is then applied which acts as a blotter, drawing the penetrant out of the discontinuity. The penetrant drawn from an opening on the surface indicates the presence and location of a discontinuity. The four steps are illustrated in Figure 11.

There are two basic classification of the penetrant method, both using a similar principle. One uses a visible dye and the other uses a fluorescent dye which is only visible with exposure to UV light. Visible penetrant is usually red in color to provide a contrast against the white developer background. Normal white light is usually sufficient to view the discontinuities.

Fluorescent penetrants provide a greenish yellow indication against a dark background when viewed in darkened area under a black (ultraviolet) light source. The fluorescent method is inherently more sensitive due to the fact that human eye can more easily discern a fluorescent indication.

PT is widely applicable on magnetic and non-magnetic materials, but it is particularly useful on nonmagnetic materials such as aluminum, magnesium, and austenitic stainless steels where MT examination cannot be used. It is also useful for locating cracks or other discontinuities which may cause leaks in containers and pipes.

There are two common methods of recording a PT indication for evaluation. A photo may be taken of the discontinuities exposed by the examination. Another method involves the application of clear plastic tape over the indication. When the tape is lifted off the test surface, the indication will adhere to the tape and may be transferred to the inspection report for future reference. These techniques also apply to MT method.

PT method is relatively inexpensive. The process is simple and the operators find little difficulty in learning to apply it properly. The success of this method, like most other examination methods, depends on the visual acuity of the inspector. It should be pointed out that some substances in penetrants can have deleterious

effect on either welds or base metals and can affect the service life of the weld or application of the product. Penetrants are difficult to remove completely from discontinuities, and if corrosive to the material, or otherwise not compatible with the product application, they should be avoided.

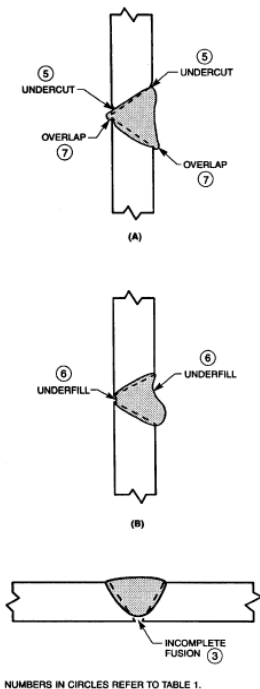


Figure 10: Groove Weld Discontinuities

Magnetic Particle Examination (MT)

This method is used for locating surface or near surface discontinuities in ferromagnetic materials. MT is based on the principles that magnetic lines of force will be distorted by a change in material continuity, i.e. discontinuity creating a magnetic field or flux leakage (See Figure 12).

A weldment can be magnetized by passing an electric current through the weld area (direct magnetization) or by placing the weldment in a magnetic field (indirect magnetization). When the magnetic field has been established within the workpiece, magnetic particles (medium) are applied to the surface to be examined. The magnetic particles can be dry or suspended in a liquid. Discontinuities can be further enhanced using fluorescent magnetic particles and observing them under black light. After removal of excess particles, the remaining particles trapped in the leakage field of a discontinuity reveal the location, shape, and size of a detectable discontinuity. These indications usually are distinguished by their appearance as sharp, well defined lines of medium against the background of the weld or heat-affected zone surface.

MT can be very beneficial as an in-process evaluation technique. Assurance of a sound weld before the weld is completed may prevent costly repair of the final product. In-process MT has become more of a common practice due to the portability of modern lightweight equipment. This advantage aids in reducing production time.

The cost of MT is considerably less expensive than radiography (RT) and ultrasonic (UT) – both in terms of the equipment cost and the cost of training the personnel. Using MT, the inspector obtains an instant visible indication of the size and orientation of the discontinuity, and allows the inspector to judge if the discontinuity is acceptable or rejectable. Compared to PT, this method has the advantage of revealing discontinuities that are not open to the surface, and therefore not detected by PT. MT is generally faster, requires less surface preparation, and is therefore usually more economical than PT (neglecting equipment costs).

The MT method is limited to ferromagnetic materials. Welded joints made between metals of dissimilar magnetic characteristics may create irrelevant magnetic particle indications even though welds themselves are sound. Most weld surfaces are acceptable for MT after the removal of slag, spatter or other extraneous material which may mechanically hold the test medium.

PLEASE REFER TO THE WRITEUP FOR THE PT METHOD FOR INFORMATION ON RECORDING MT INDICATIONS FOR EVALUATION.

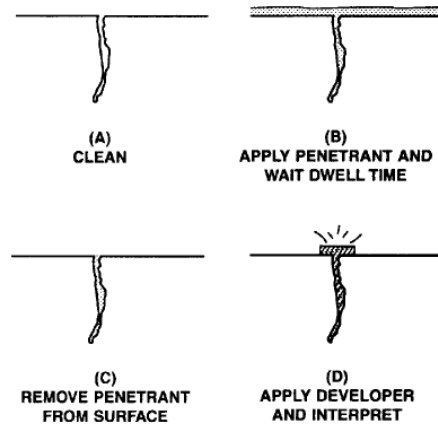


Figure 11: Steps in Penetrant Testing

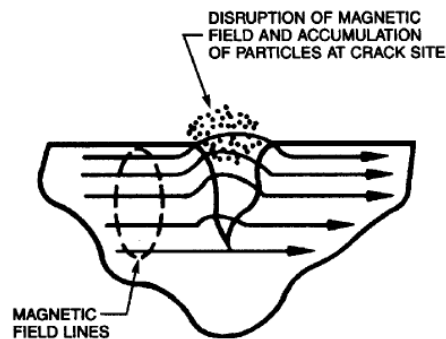


Figure 12: Magnetic Field Leakage

Radiographic Examination (RT)

RT is a method of NDE that utilizes radiation to penetrate a weld and reveal information about its internal condition. When a weld is exposed to penetrating radiation, some radiation will be absorbed, some scattered, and some transmitted through the weld onto recording device (See Figure 13). Most conventional RT techniques used today involve exposures that record a permanent image on a photographic film, although other image recording methods are also used.

The basic process of radiographic examination involves two general steps:

- 1) The making of radiograph, and
- 2) Interpretation of the radiograph

The essential elements needed to carry out these two operations are:

- 1) A source of radiation
- 2) Weld to be radiographed
- 3) Weld identification markers, station markers and image quality indicators
- 4) An X-ray film enclosed in a light tight film holder
- 5) A skilled person capable of producing an exposed film
- 6) A means of chemically processing the exposed film
- 7) A skilled person capable of interpreting and evaluating the radiographic images

Two types of radiation sources commonly used in weld inspection are X-ray machines and radioactive isotopes. X-radiation is produced by machines which range from portable, low energy units capable of radiographing relatively thin objects, to mammoth linear accelerators and betatrons capable of radiographing thick steel welds up to 20 in. of steel. Gamma radiation is emitted by radioisotopes, the two most common being Cobalt 60 which will penetrate to approximately 5 in. of steel, and Iridium 192 which is limited to a steel thickness of approximately 3 in.

The radiographic process is dependent upon varying amount of radiation being absorbed by different areas of the weld. The differences in the absorption occurring during the exposure process account for the dark and light regions on the radiograph. The interpretation of a radiograph involves identifying the images resulting from various light and dark regions on the film. The dark regions represent the easily penetrated parts of the weld (i.e., thin sections and most discontinuities) while the lighter areas represent the more difficult areas to penetrate (i.e. thick sections). Figure 14 illustrates several types of weld discontinuities a film interpreter may encounter in the evaluation of weld radiographs.

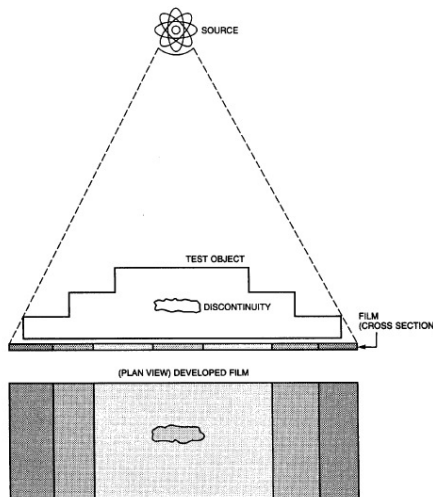


Figure 13: Making a Radiograph

A significant limitation of radiographs is that discontinuities must be favorably aligned with the radiation beam to be reliably detected. This is usually not a problem for discontinuities such as porosity or slag since they are usually round in cross section and align with a beam from any direction. This is not the case with planar discontinuities such as cracks, incomplete fusion, and laminations. There are several other limitations associated with radiography:

- 1) It presents a potential radiation hazard to both personnel and the public
- 2) The cost of radiographic equipment, facilities, safety programs and related licensing is relatively high
- 3) There is usually a relatively long time, when compared to MT, PT and VT, between the exposure process and the availability of results
- 4) Accessibility to both sides of the workpiece is required to set up the apparatus.

However, there are some advantages as well:

- 1) It is generally not restricted by type of material
- 2) Both surface and subsurface discontinuities may be detected
- 3) Radiographic images aid in characterization (identification) of discontinuities
- 4) It provides a permanent record for future review
- 5) The radiograph may be used to make a map to locate the exact defect orientation and assist in the removal of the unacceptable condition in the weldment

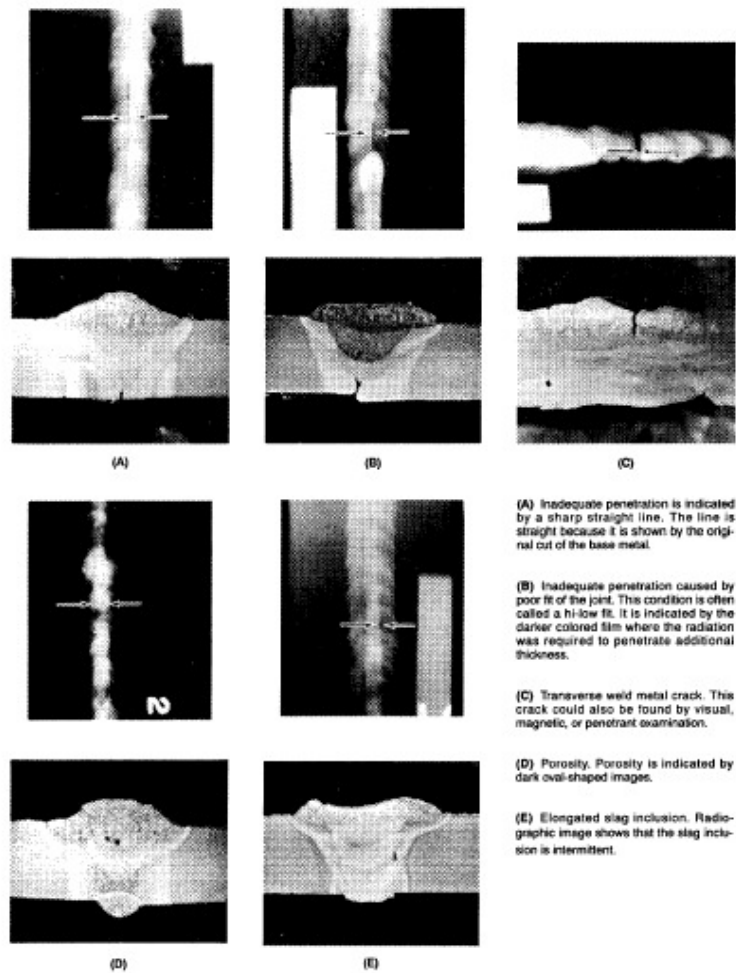


Figure 14: Typical Radiographs of weld discontinuities

Ultrasonic Examination (UT)

UT is becoming one of the most widely used methods of NDE. Its primary application is the detection and characterization of internal discontinuities. It is also used to detect surface discontinuities, to define bond characters, and to measure thickness. In this method, high frequency sound waves are introduced into the material to detect surface and subsurface discontinuities. The sound waves travel through the material with some loss of energy (attenuation) and are reflected at interfaces. The reflected sound beam is detected and analyzed to define the presence and location of discontinuities.

UT is usually performed with either longitudinal waves (straight beam) or shear waves (angle beam). In longitudinal beam testing (commonly used to examine plate material), sound in the form of ultrasonic vibrations is introduced into part perpendicular to the entry surface by straight beam search unit (Figure 15). When the entry surface and the back surface are parallel, a back reflection will appear on the display screen. A discontinuity lying between the front and back surfaces will also be displayed on the display screen. By measuring the height of the reflection on the display screen, from a real or artificial discontinuity of a known size, a reference level can be established such that reflections from discontinuities of unknown sizes may be evaluated.

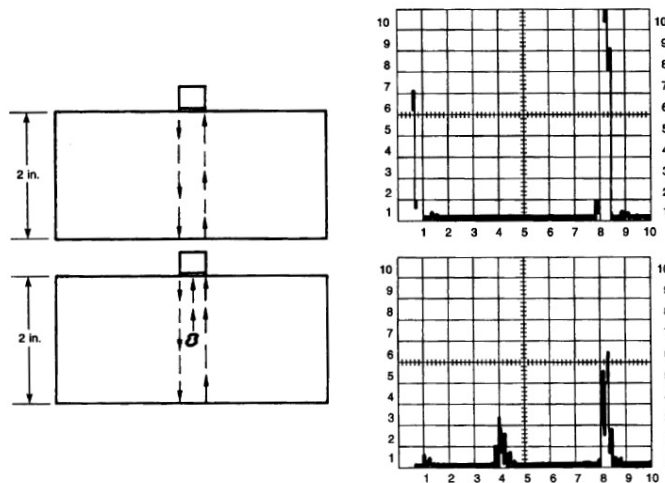


Figure 15: Example of Longitudinal Testing

The angle beam technique (Figure 16) is used for the examination of welds. Ideally, only discontinuities should appear on the display screen during the angle beam inspection. This is not always the case, however, since the geometrical boundaries of the part often reflect sound in same manner as a discontinuity. Therefore care must be taken during UT of joints with complex geometries (such as welds with backing bars) to assure that the indications are the result of the presence of discontinuities and not simply due to the configuration of the joint.

It is generally desirable to have the sound beam intercept the plane of the discontinuity at or near 90° so that the maximum amount of sound is reflected to the transducer. However, cracks that are not oriented perpendicular to the UT beam can be detected because their surfaces are not smooth and sound is reflected from the facets that are approximately perpendicular to the beam. Selection of test surface for scanning with the search unit depends upon accessibility. Scanning surface selection is also based on the weld shape and structure. Since it is important to intercept the discontinuity at or near 90° , it is common for more than one angle unit to be used to examine a particular weld.

The principal advantages of UT over other NDE methods for metal parts are:

- 1) Allows the detection of discontinuities deep in the part
- 2) High sensitivity permits the detection of very small discontinuities
- 3) Greater accuracy in determining the position of internal discontinuities, estimating size and characterizing the orientation, shape and nature
- 4) Only one surface need be accessible
- 5) Provides almost instantaneous indication of discontinuities. This makes the method suitable for immediate interpretation, automation, rapid scanning, production line monitoring, and process control. With some systems, a permanent record of inspection results can be made for future reference
- 6) Scanning ability enables examination of a volume of a metal extending from front to back surface of a weld

Some disadvantages of UT include:

- 1) Manual operation require careful attention by experienced technicians
- 2) Extensive technical knowledge is required for the development of examination procedures and the interpretations of indications
- 3) Parts that are rough, irregular in shape, very small or thin or in-homogenous are difficult to examine
- 4) Discontinuities that are present in a shallow layer immediately beneath the examination surface may not be detectable

- 5) Couplants are needed to provide effective transfer of UT wave energy between search units and the part being examined
- 6) Reference standards which duplicate the exact examination conditions are needed for calibrating the equipment

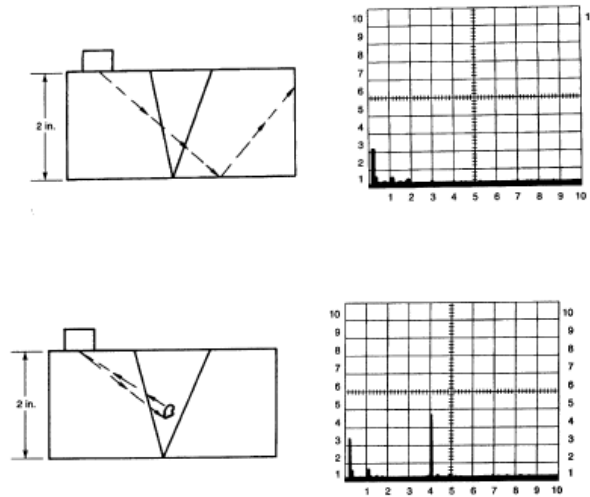


Figure 16: Angle Beam Technique (Top – No Discontinuity, Bottom – Discontinuity)

Interrelationships among Welding Processes, Discontinuities, and Examination Methods

Table 2 relates the examination methods to various types of discontinuities. Table 3 relates the joint types to the applicable NDE methods.

Table 2: Common Weld Inspection Methods vs. Discontinuities

Discontinuities	Inspection Methods						
	RT	UT	PT	MT	VT	ET	LT
Porosity	A	O	A	O	A	O	A
Slag inclusions	A	O	A	O	A	O	O
Incomplete fusion	O	A	U	O	O	O	U
Incomplete joint penetration	A	A	U	O	O	O	U
Undercut	A	O	A	O	A	O	U
Overlap	U	O	A	A	O	O	U
Cracks	O	A	A	A	A	A	A
Laminations	U	A	A	A	A	U	U

Notes:

- a. Surface
- b. Surface and slightly subsurface
- c. Weld preparation or edge of base metal
- d. Magnetic Particle Examination is applicable only to ferromagnetic materials.
- e. Leak Testing is applicable only to enclosed structures which may be sealed and pressurized during testing.

Legend:

- RT—Radiographic testing
- UT—Ultrasonic testing
- PT—Penetrant testing, including both DPT (dye penetrant testing) and FPT (fluorescent penetrant testing)
- MT—Magnetic particle testing
- VT—Visual testing
- ET—Eddy current testing
- LT—Leak testing
- A—Applicable method
- O—Marginal applicability (depending on other factors such as material thickness, discontinuity size, orientation, and location)
- U—Usually not used

Table 3: Applicable Examination Methods vs. Five Weld Joint Types

Joints	Inspection Methods						
	RT	UT	PT	MT	VT	ET	LT
Butt	A	A	A	A	A	A	A
Corner	O	A	A	A	A	O	A
Tee	O	A	A	A	A	O	A
Lap	O	O	A	A	A	O	A
Edge	O	O	A	A	A	O	A

Legend:

RT—Radiographic examination

UT—Ultrasonic testing

PT—Penetrant examination, including both DPT (dye penetrant testing) and FPT (fluorescent penetrant testing)

MT—Magnetic particle examination

VT—Visual testing

ET—Electromagnetic examination

A—Applicable method

O—Marginal applicability (depending on other factors such as material thickness, discontinuity size, orientation, and location)

Sources:

1. AWS B1.10 – Guide for the Nondestructive Examination of Welds

***** END OF THE ARTICLE *****

About CoDesign Engineering:

CoDesign Engineering specializes in the core business of providing training and consultancy for design and fabrication of ASME code pressure vessels, and the ecosystem that includes piping, welding, valves, geometric dimensioning and tolerancing, process improvement, and engineering management. Some of the training courses (lasting from two days to five days) that we provide include:

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- Know Your Process Piping
- Know Your ASME Section VIII Pressure Vessel Code
- Know Your Shell & Tube Heat Exchangers
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Ramesh Tiwari holds a Master's degree in Mechanical Engineering from Clemson University in South Carolina, and is a registered Professional Engineer from the state of Maryland in the United States. He has over 22 years of experience designing pressure vessels, heat exchangers and tanks. Ramesh is a member of ASME Section VIII Subgroup on Heat Transfer Equipment, and member of ASME B31.1 IWG for Power Piping. He is also an approved pressure vessel instructor at National Thermal Power Corporation (NTPC), a premier thermal power generating company in India; and TUV India of TUV Nord Group, one of the world's largest Inspection, Certification and Testing Organizations.

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