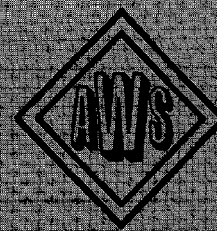


CHAPTER 11:**NONDESTRUCTIVE
EXAMINATION PROCESSES****Introduction**

The knowledgeable welding inspector will have the authority under some specifications to accept welds by visual examination alone, but he cannot certify some of the welds in a weldment or structure so easily. The welding inspector will need help in collecting the necessary evidence of specification compliance.

To collect the necessary evidence, the welding inspector can use one or more of the following methods:

- Nondestructive examination performed by technicians qualified in accordance with the guidelines of the American Society for Nondestructive Testing Recommended Practice No. SNT-TC-1A, when required
- Chemical analysis qualified to ASTM standards
- Metallurgical analysis
- Mechanical testing

This chapter will help the welding inspector to:

- Know the principal features to be considered when choosing a nondestructive examination method.
- Understand how this examination differs in different applications of welding.
- Understand fundamental aspects of the various techniques of nondestructive examination.

- Relate the proper examination technique to a given weld joint design and welding process.
- Know the responsibilities in regard to sample selection, examination methods, retests, repairs, and evaluation of data.

Selection of Examination Method

There are three principal features to be considered when choosing an examination method:

- Limitations of the examination method
- Acceptance standards
- Economics

Limitations of the Examination Method

The limitations of the examination method are a consideration in determining which method will provide the best results for a particular test. For example, radiography can detect cracks that are aligned parallel to the radiation beam; such cracks are usually normal to the plate surfaces. However, radiography usually cannot detect laminations in the plate; ultrasonic examination can detect laminations in the plate and, with the proper choice of technique, can usually be relied upon to detect cracks normal to the plate surfaces.

Acceptance Standards

The statement, "The weld shall be radiographically examined," has no meaning unless acceptance standards are stated. The

11-2

acceptance standards must state each type of discontinuity and whether or not such a discontinuity is permissible. If a particular type of discontinuity is permissible, then the acceptance standards must specify the maximum size at which the discontinuity is acceptable. Acceptance standards are an integral part of almost all of the codes and standards listed in Appendix A and are commonly used as references in purchase specifications.

Economics (Cost)

Each examination method has a different cost in a particular situation. Two basic cost factors to be considered in the selection of a nondestructive examination method are the initial equipment availability and cost, and the cost of performing the tests. Visual examination is almost always the cheapest, but is also limited to the detection of surface discontinuities. In general, costs of radiographic, ultrasonic, and eddy current examinations are greater than those of visual, magnetic particle, and liquid penetrant methods of examination.

Selection of the proper examination method can be quite complex. In many cases, a single test may not be adequate. It may be necessary to apply two or more tests to assure complete coverage. For example, the examination of a large carbon steel weldment might include radiography for subsurface evaluation and magnetic particle testing for an examination of the surface. For critical applications or large volumes of testing, it is suggested that help be obtained from a competent laboratory or consultant.

Examination Methods and Limitations

Visual Examination

As the welding inspector gains experience, it will be noted that a weld displays its pedigree to a large degree in its surface appearance. When the welding inspector has seen that the preparation of the joint was good, and when he knows that the



HOPTON JONES INDUSTRIES

welder had the requisite ability, the odds favor a good-looking weld being sound and within specification.

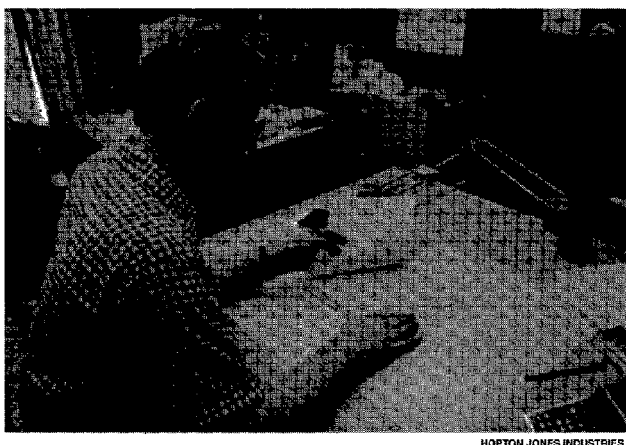
Remember: The evidence needed by the inspector is provided by the governing code, engineering standards, job specifications, or job requirements. The welding inspector cannot accept less nor ask for more than is required by these documents.

Visual examination is limited to the detection of surface discontinuities. However, visual examination, when conscientiously applied before, during and after welding, can prevent the vast majority of those discontinuities that would be detected by other examination methods. In fact, the ability to prevent many discontinuities before the weld is complete is perhaps the most important feature of visual examination.

Visual Examination Practice: Any good visual weld examination program requires that the inspector have a working knowledge of:

- Applicable codes, standards and specifications, including weld acceptance criteria
- Workmanship standards
- Welding processes being used
- Good weld fabrication practices

The welding inspector's responsibilities commence before welding begins. In fact, these



HOPTON JONES INDUSTRIES

initial steps are critical enough to set the tone for the resulting quality of the entire project. If these preliminary duties are thoroughly attended to, the attainment of quality welding will be more assured. Some of the items which may be checked include:

- Review applicable documentation
- Check welding procedures
- Check individual welder qualifications
- Establish hold points
- Develop an inspection plan
- Develop a plan for recording inspection results and maintaining those records
- Develop a system for identification of rejects
- Check condition of welding equipment
- Verify base metal and filler metal identifications
- Check quality and condition of base and filler metals
- Check weld preparations
- Check joint fit
- Check adequacy of alignment devices
- Check weld joint cleanliness
- Check preheat, when required

Once welding begins, the welding inspector's duties are primarily related to the assurance that the welding is being done in accordance with the welding procedures and any applicable standards. Here, the goal is to identify problems before they

occur, or at least as soon as possible after they occur, so they can be corrected in the most economic and effective way. Below are some of the items which should be checked during the actual welding operation:

- Check welding variables for compliance with welding procedure
- Check quality of individual weld passes
- Check interpass cleaning
- Check interpass temperature
- Check placement and sequencing of individual weld passes
- Check back-gouged surfaces
- Arrange for in-process NDE, when required

After the welding has been completed, the role of visual examination is simply the verification that all of the preceding steps have been successfully completed and the resulting weldment is acceptable. Some of the items to be checked include:

- Check finished weld appearance
- Check weld size
- Check weld length
- Check dimensional accuracy of weldment
- Arrange for additional NDE, when required
- Monitor postweld heat treatment, when required
- Prepare inspection reports

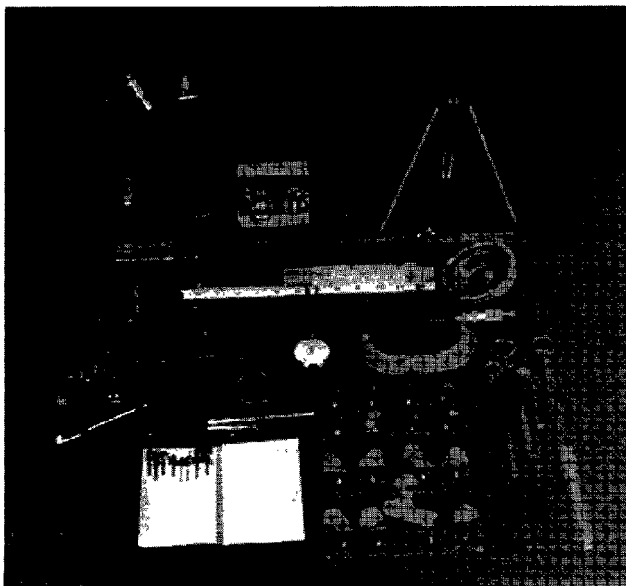
There are numerous advantages of visual examination, including: low cost to apply, little need for expensive equipment, and the ability to find problems when they occur to allow for economical and expedient correction.

11-4

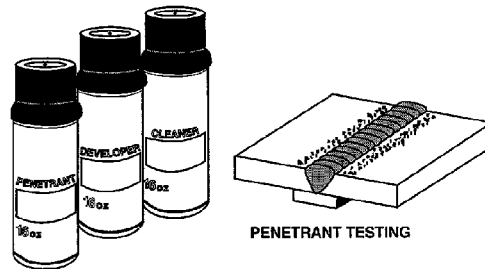
Penetrant Testing (PT)

Penetrant testing is a sensitive method used for locating discontinuities, such as cracks and porosity, in nonporous materials. The discontinuities must be clean and open to the surface. The method employs a penetrating liquid which is applied to the surface to be examined and which enters the discontinuity. The excess penetrant is then cleaned from the surface. Any penetrant which subsequently exudes from openings and causes discoloration of developer powder on the surface indicates the location of a discontinuity.

There are two general classifications of penetrants: visible dye and fluorescent. They differ in that the visible dye can be observed under normal white light, while the fluorescent type requires an ultraviolet (or black) light to produce an indication. Use of fluorescent penetrants results in a more sensitive test, simply because our eyes can more readily detect a fluorescent indication. Consequently, for critical applications where even the smallest discontinuities must be detected, the fluorescent penetrant method would be desirable.



VISUAL INSPECTION TOOLS



In general, the penetrant test consists of four simple steps, including: precleaning the test surface, application of the penetrant which remains for some prescribed time (called the "dwell time"), removal of excess penetrant from the test surface, and application of the developer. Following the application and drying of the developer, all indications are evaluated in accordance with applicable standards. For a detailed explanation of these steps, please refer to ASTM E-165.

Uses

This method is applicable to magnetic materials; however, it is particularly useful on nonmagnetic materials such as aluminum, magnesium and austenitic stainless steels, which cannot be examined by magnetic particle testing.

Advantages

Penetrant testing is relatively inexpensive and reasonably rapid. The process is simple and operators find little difficulty in learning to apply it properly. There are few, if any, false or nonrelevant indications on reasonably smooth surfaces.

Limitations

The main limitation of penetrant testing is that discontinuities must be clean and open to the surface to be detected. Some substances used as penetrants can have a deleterious effect on welds and base metals and can affect the service life of the weldment or end use of the product. Penetrants are difficult to remove completely from discontinuities and if they are corrosive to the

material or otherwise not compatible with the use of the product, they should be avoided.

The contour of the surface being examined should not contain sharp depressions between beads or weld ripples that would interfere with complete cleaning and excess penetrant removal. Otherwise, you may observe false or irrelevant indications. If these conditions do exist, the weld surface should be ground smooth before inspection.

Interpretations

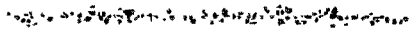
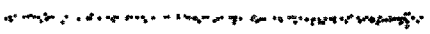
It is important that the technician not reduce the recommended dwell times for penetrant or developer. Large cracks and voids will reveal themselves quickly, but those might be found without this aid. Tightly closed cracks absorb the penetrant slowly and respond to the developer equally slowly.

Inadequate removal of the superficial penetrant will give many false indications, such as a general glow under the blacklight for fluorescent penetrant testing, or a pink coloration of the developer with visible dye penetrant testing. Precleaning the surface without adding more penetrant will give a clearer indication, showing only seepage from surface discontinuities. Indications which repeat at the same location throughout several cleanings undoubtedly reveal open discontinuities.

Care must also be taken to avoid spraying cleaner directly on the test surface between application of the penetrant and developer.

Magnetic Particle Testing (MT)

Magnetic particle testing is used for locating surface or near surface discontinuities in ferromagnetic materials. This method involves the establishment of a magnetic field within the material to be examined. The pattern of discontinuities is revealed by the buildup of iron powder particles which are applied to the surface, either as a dry powder or suspended in a liquid.

IF YOU SEE:	INDICATION	YOU HAVE:
A CONCENTRATION OF RED SPOTS		PITS AND POROSITY
A CONTINUOUS STREAK WHICH BLEEDS UP RAPIDLY		LARGE CRACK OR OPENING
A BROKEN LINE OF DOTS WHICH TAKES SEVERAL MINUTES TO COME UP		CRACK OR COLD SHUT
A SERIES OF RED DOTS FORMING AN IRREGULAR LINE		FATIGUE CRACK, PARTIAL WELD OR LAP

The particles may be dyed for greater visibility or coated with fluorescent dye to be viewed under ultraviolet light with the same improved sensitivity associated with fluorescent penetrant testing. The type of surface and the type of discontinuity suspected should determine the material selected.

A test material or component can be magnetized either by passing electric current through it or by placing it in a magnetic field. The electric current used to generate the magnetic field may be alternating current (ac), direct current (dc) or half-wave rectified direct current (hwdc). Alternating current is generally limited to the detection of surface discontinuities; however, its characteristically changing magnetic field tends to increase the particle mobility on the surface to result in an improvement of the test sensitivity when examining rough surfaces.

A dc magnetic field differs from the ac field in that it tends to penetrate more deeply into the test piece, which results in the ability to detect

11-6

discontinuities slightly below the surface. However, the magnetic particles do not tend to move as readily on the surface as with ac. Half-wave rectified dc combines the benefits of both types of magnetizing current: the enhanced particle mobility of ac and the deeper penetration of dc.

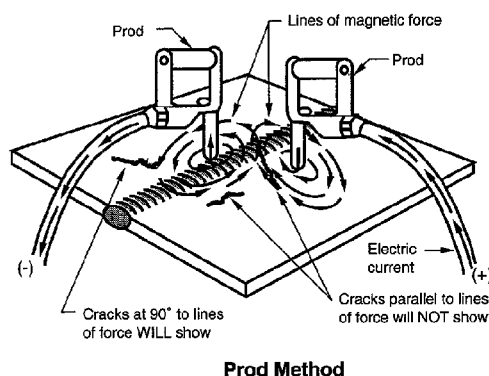
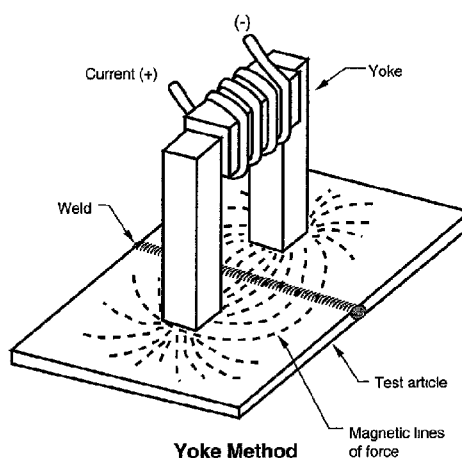
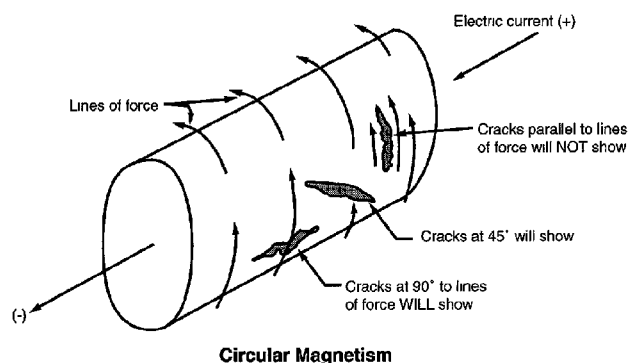
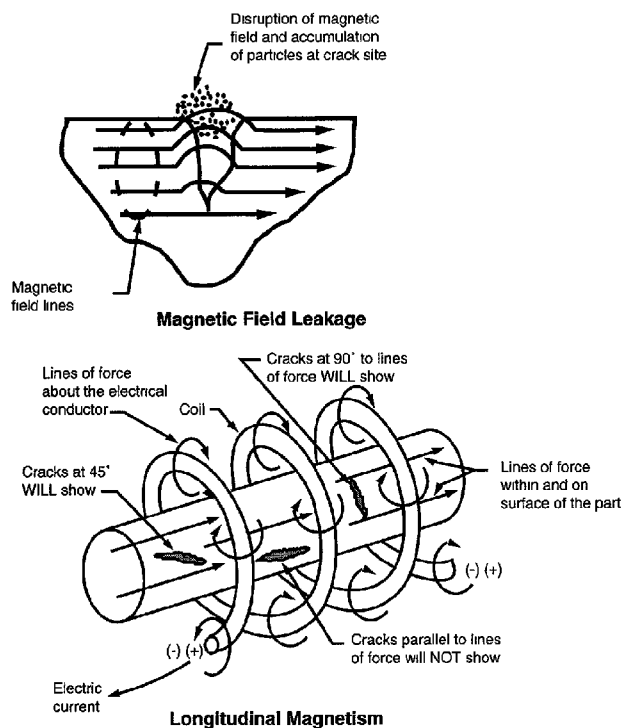
Uses

Magnetic particle testing can provide a great deal of information about the quality of weldments. This method may be used to inspect welds, plate edges prior to welding and weld repairs. This method is capable of detecting:

- Surface cracks of all kinds in the weld or base metal
- Laminations or other discontinuities on the prepared edge of the base metal
- Incomplete fusion (if at or near the surface)
- Undercut
- Subsurface cracks (if it occurs near enough to the surface to cause an interruption of the magnetic field at the surface)

Advantages

The basic equipment for magnetic particle testing is relatively simple. It includes devices for creating a magnetic field of the proper strength and direction. There might also be controls for adjusting the current and an ammeter to indicate the amount of magnetizing current for each examination.



Compared to penetrant testing, this method has certain other advantages. It reveals discontinuities that are not open to the surface or filled with some substance (cracks filled with carbon, slag or other contaminants may not be detectable using penetrant testing). Magnetic particle testing is also generally faster and more economical than penetrant testing, unless extremely large test surfaces are involved. Another advantage is the fact that there is less cleaning required prior to examining the part with magnetic particle testing.

Limitations

The magnetic particle method of examination is applicable only to ferromagnetic materials in which the deposited weld metal is also ferromagnetic. This method cannot be used to examine nonferromagnetic materials such as aluminum, magnesium or the austenitic stainless steels.

Difficulties may arise when examining weldments where the magnetic characteristics of the deposited weld metal differ appreciably from

those of the base metal or where the magnetic field is not properly oriented. Joints between metals of dissimilar magnetic characteristics may create magnetic particle indications even though the joints themselves are sound.

It's important that the technician not expect the magnetic particle method to find deep-seated discontinuities. They are more readily discovered using other examination methods such as radiography or ultrasonic testing. These methods, and the visual examination of sectioned test samples, can be used to qualify the magnetic particle procedure for subsurface examination.

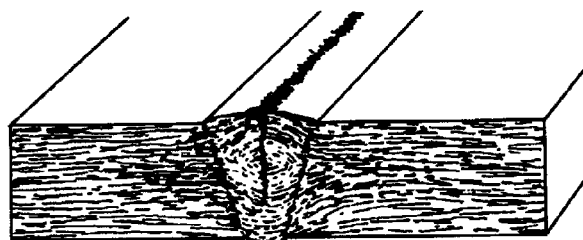
For discovery of discontinuities lying in all orientations the magnetic particle test must be applied in at least two directions, approximately 90° apart. Only then can the tester be assured that all discontinuities will be revealed.

Radiographic Testing (RT)

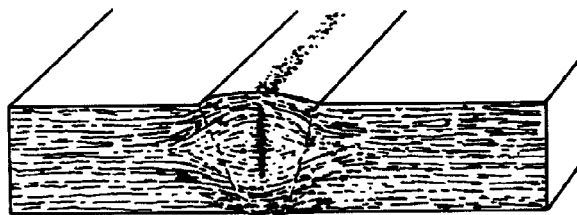
Radiographic testing is suitable for all materials. However, the applicability of radiography for weld examination depends a great deal upon the weld joint location, joint configuration and material thickness. Almost any



MAGNAFLUX CORP.



SURFACE CRACKS GIVE POWDER PATTERNS THAT ARE SHARPLY DEFINED, TIGHTLY HELD, AND USUALLY BUILT UP HEAVILY. THE DEEPER THE CRACK, THE HEAVIER THE BUILD-UP OF POWDER.



SUBSURFACE CRACKS PRODUCE A LESS SHARPLY DEFINED, FUZZY PATTERN. THE POWDER IS ALSO LESS TIGHTLY ADHERENT.

11-8

weld thickness can be radiographed, but insufficient joint access may prevent best use of the method. The welding inspector should keep this limitation in mind when asking for radiographic examinations.

Radiography uses X- or gamma radiation that penetrates through the part and produces an image on a film or plate. The density of the material in a discontinuity (air in the case of a crack, incomplete fusion or porosity) is less than that of the solid metal. Different density materials attenuate the radiation in different amounts and consequently produce optical density differences on the film or plate.

Material density can be affected by the material itself (For example, tungsten is much denser than steel or aluminum, so tungsten is more effective at preventing the radiation from passing through, resulting in a low density indication on the film.) or by the thickness of a given material (The thicker the material, the more effective it is at stopping the radiation and thus producing a lighter film image.). The selection of the radiation source (energy of the emitted rays) for a particular thickness of weld is a critical factor. If the energy of the source is too high or too low for a given thickness of material, then low contrast and poor radiographic sensitivity result. The use of a variable light intensity viewer is helpful when viewing and analyzing radiographs.

There must also be some means of determining the film density at various points. This is usually accomplished through the use of a device referred to as a densitometer. To indicate the acquired sensitivity of a given radiograph, a device referred to as an image quality indicator, or penetrameter, is placed adjacent to the area of interest. This penetrameter is a particular thickness, based on the thickness of the test part, and contains a series of holes having different diameters. The sensitivity of the radiograph is therefore determined by which of the three holes is visible on the radiograph.

Advantages

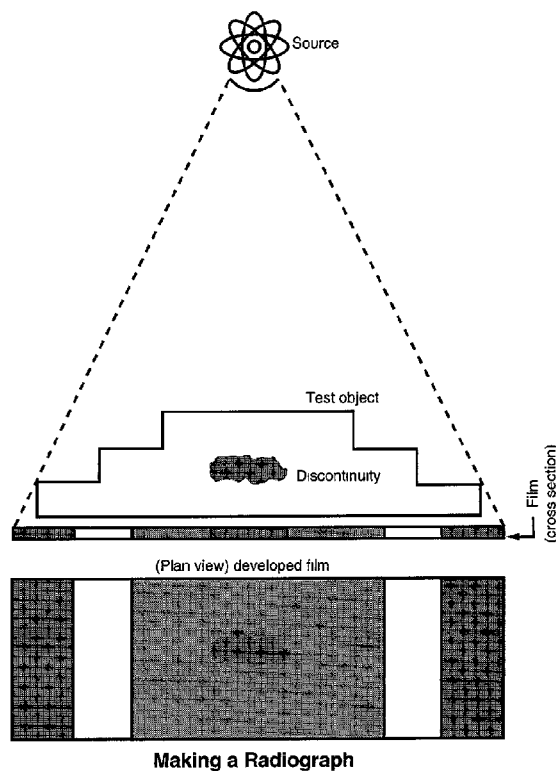
Radiography can detect:

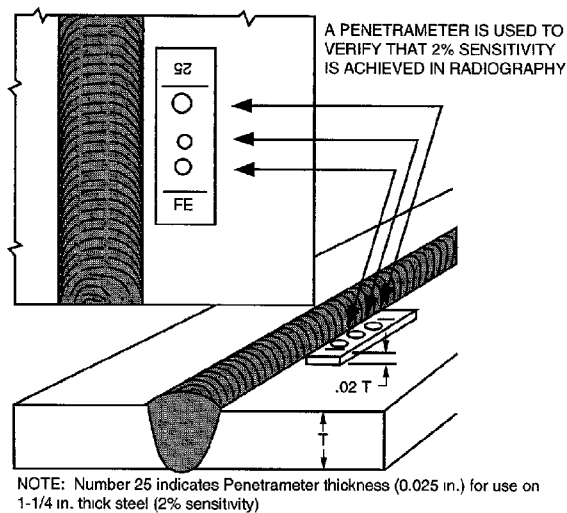
- Surface discontinuities such as undercut, incomplete joint penetration, excessive weld reinforcement, underfill, etc.
- Subsurface discontinuities that cannot be detected with visual, magnetic particle or penetrant methods and may not be detected by the ultrasonic method.

Limitations

The cost of radiography usually goes up as the joint becomes more complex, and the amount of information that can be obtained becomes more limited.

Discontinuities must be more or less aligned with the radiation beam. This is not a problem for slag or porosity because these are usually round in cross section and are aligned with the beam from any direction. However, cracks, incomplete fusion and incomplete joint penetration must be aligned with the beam to be detected. Laminations and lamellar tearing are almost never detected with



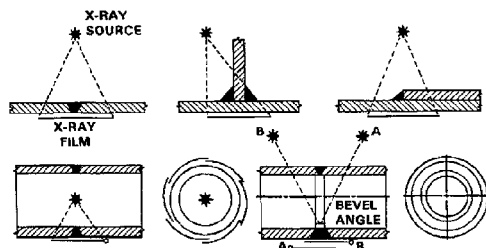


Typical Penetrator

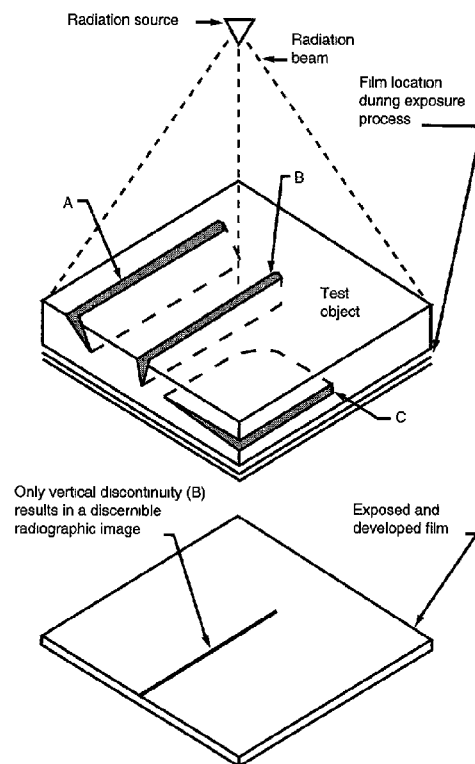
radiography due to their inherent orientation with respect to the radiation.

The high cost of radiation sources and related equipment and facilities tends to be one of the limitations of this method. There must be a high capital expense to initially set up for this type of testing.

The use of radiography has one negative aspect not associated with the other nondestructive methods, and that is the radiation hazard. Excessive exposure to radiation from an X-ray machine or a radioactive isotope cannot be detected by any of the human senses but may cause disease, permanent injury or death. All states require that radiographers be licensed or have special training, or both. Radiography is, however, a safe operation when conducted in accordance with established procedures.



Shown here are the typical arrangements of the x-ray source and film. The angle of exposure and the geometry of the weld influence interpretation of the negative.



Detection of planar defects at various orientations by radiography

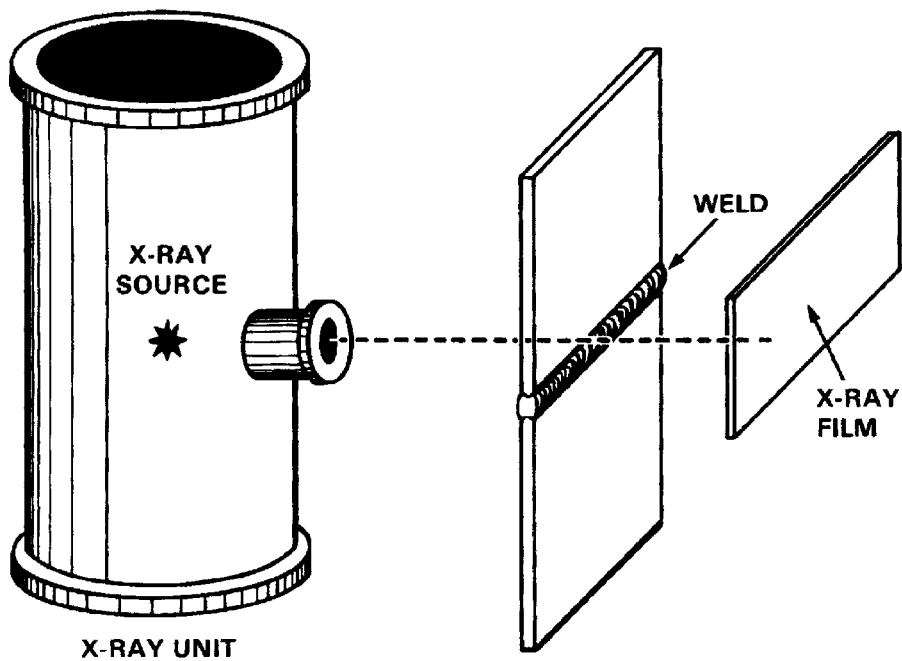
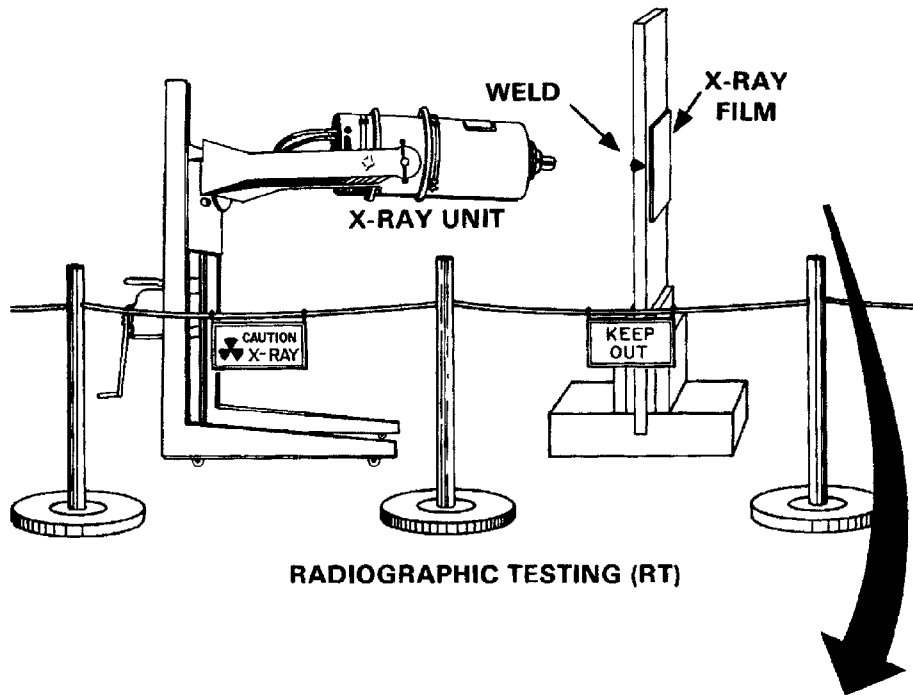
Ultrasonic Testing (UT)

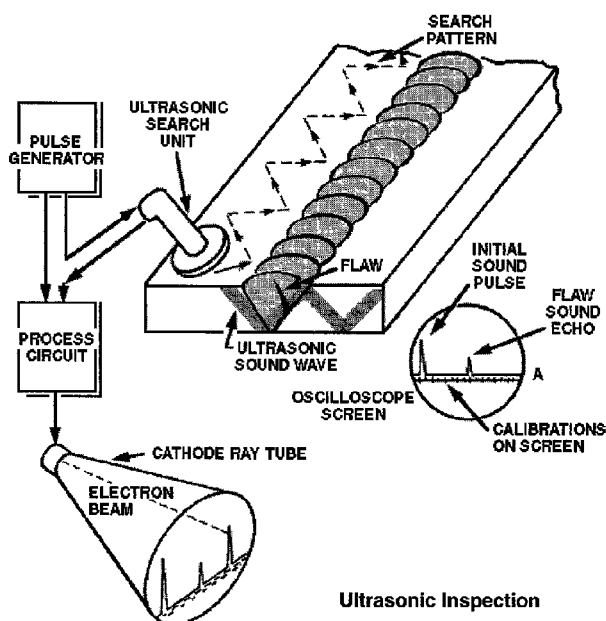
The ultrasonic method is applicable to almost all materials. The ultrasonic method uses the transmission of mechanical energy in wave form at frequencies above the audible range. Reflections of this energy by discontinuities in metals are detected in a manner somewhat similar to the detection of reflected light waves in transparent media.

Uses

In the pulse-echo technique, a transducer transmits a pulse of high frequency sound into and through the material and the reflected sound is received from a discontinuity, the opposite surface or other surfaces of the part. The reflected sound is received as an echo which, together with the original pulse, is displayed on the screen of a cathode ray tube (CRT).

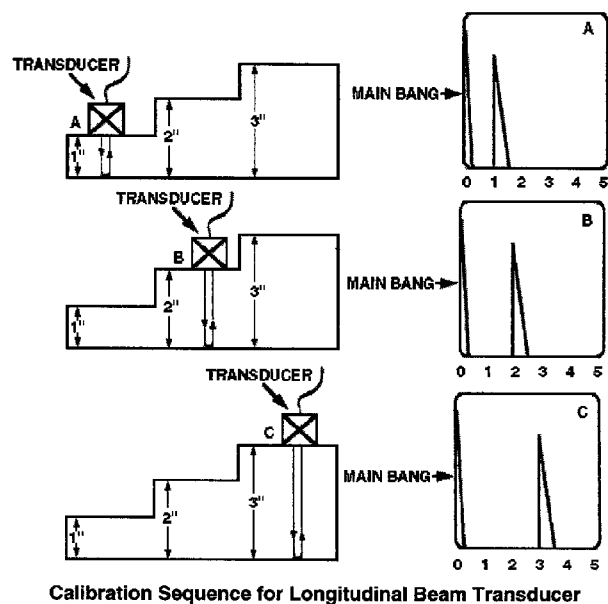
11-10





Before testing is begun, the instrument is calibrated against a reference standard. When the sound beam intercepts the plane of discontinuity at or near 90°, a maximum reflected signal will return to the transducer. In scanning welds, this is achieved by beams angled into the work, through a lucite wedge and into the work through water, oil or similar couplant material.

When examining groove welds which require ultrasonic testing under the AWS Structural Welding Code, the technician will find the procedures tightly specified in AWS D1.1. The amount of testing to be done and the equipment to be used are specified. The equipment itself must be calibrated using some type of standard reference block, such as the IIW (International Institute of Welding) calibration block. The setup used by technicians (magnitude and location of indications on horizontal and vertical scales of the CRT) are prescribed for both straight beam and angle beam testing.



Advantages

- UT can be used to detect both surface and subsurface discontinuities.
- For pulse-echo testing, access is necessary to only one side of the work.
- The size of flaws and their interface location may be determined quantitatively.
- The method is generally more sensitive for the discovery of planar type discontinuities (which are generally considered more critical) than is radiography.
- Laminations and lamellar tearing can be readily detected using ultrasonic testing.

Limitations

- Welds in some materials are very difficult to examine ultrasonically. For example, welds involving materials and processes which produce large grain size tend to scatter and disperse the sound beam; penetration of the sound beam into these materials is limited and interpretation of the results can be difficult.

11-12

- Personnel must be qualified and, in general, they require more training and experience for ultrasonic testing than for most of the other more common NDE methods.
- The scan pattern must be sufficient to pass the projected sound beam through the entire volume of the weld and heat affected zone to permit detection of possible discontinuities.
- For contact testing, the test surface used for scanning with the transducer must be smooth enough so liquid coupling may be obtained. Otherwise, the part may be placed in water and the sound wave transmitted through some length of water path. This is called immersion testing.

Eddy Current (Electromagnetic) Testing (ET)

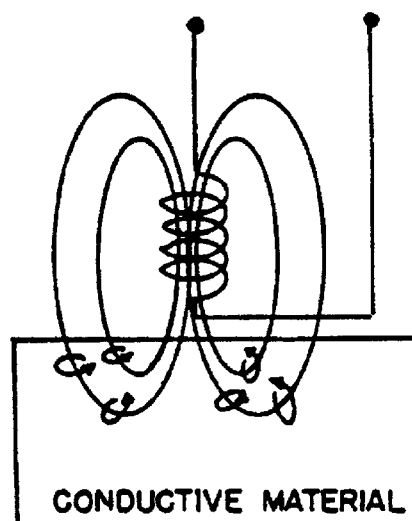
Eddy current testing requires the part under test to be subjected to the influence of an alternating electromagnetic field. The tests detect surface or subsurface discontinuities in any material that is an electrical conductor. The electromagnetic field induces eddy currents in the part and also establishes magnetic fields if the part is magnetic.

A complete separation of these two effects in magnetic materials is not readily accomplished. However, a high degree of differentiation can be obtained by specialized techniques. Information gathered by probe coils is transmitted to a test circuit and analyzed electronically. Electromagnetic field frequencies are usually in the range of 500 Hz (hertz, or cycles per second) to 5000 Hz.

Uses

Since eddy currents may be induced in any electrical conductor, eddy current testing is employed on magnetic or nonmagnetic materials.

In eddy current tests, the magnitude and direction of the eddy currents are detected by the



Induced Eddy Currents in Test Objects

coil, or by a separate coil, which acts through electronic circuitry to register the discontinuity.

In testing of magnetic materials, the distribution of magnetic flux is affected by magnetic variables. If the variation in flux is associated with discontinuities in the material, the discontinuities are detected.

Advantages

The four most significant advantages that electromagnetic testing has over other methods are:

- It can, in many cases, be completely automated; thus it provides automatic examination at high speeds and at a relatively low cost.
- Under certain circumstances, the indications produced are proportional to the actual size of the discontinuity. Thus, the tests can be useful for grading and classifying.
- Actual contact of probes with the work is not necessary; close proximity is satisfactory.
- Eddy current testing is capable of detecting many different material characteristics, including: electrical conductivity,

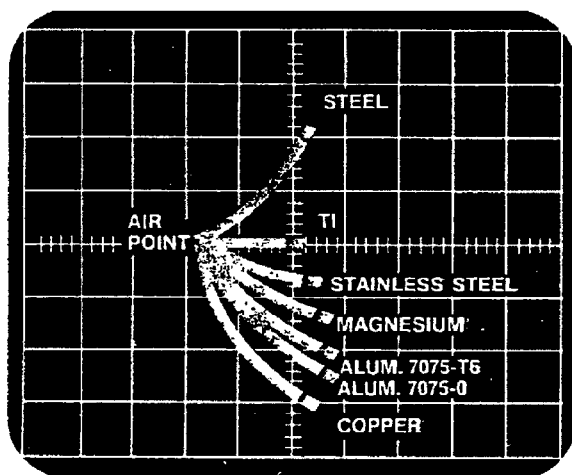
magnetic permeability, thickness, the thickness of a nonconductive coating, alloy content, heat treatment, and the presence of discontinuities at or below the surface.

Limitations

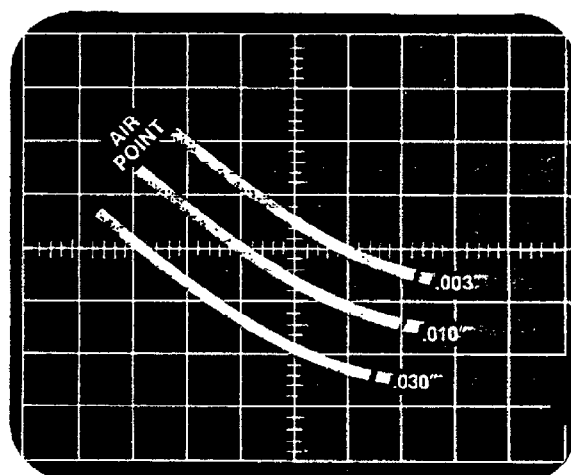
In preparing the material to be examined, any surface dirt that may be magnetic or electrically conductive must be removed. Before testing is begun, the instrument must be calibrated against a reference standard.

The design of the coil that produces the magnetic field must be appropriate for the shape of the component to be tested and the type of discontinuities that are sought. On welded tubular products, a coil (or coils) is commonly built to surround the material.

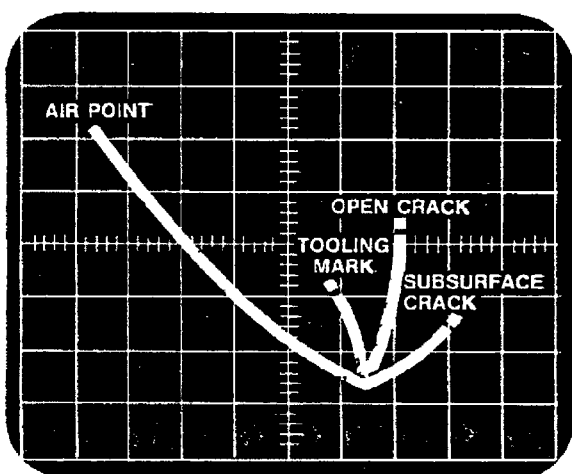
The practical limit for penetration of eddy currents in most nonmagnetic metals is approximately 1/4 in. (6 mm) below the surface. The depth of examination beneath the surface of the part depends upon the frequency chosen to excite the electromagnetic field.



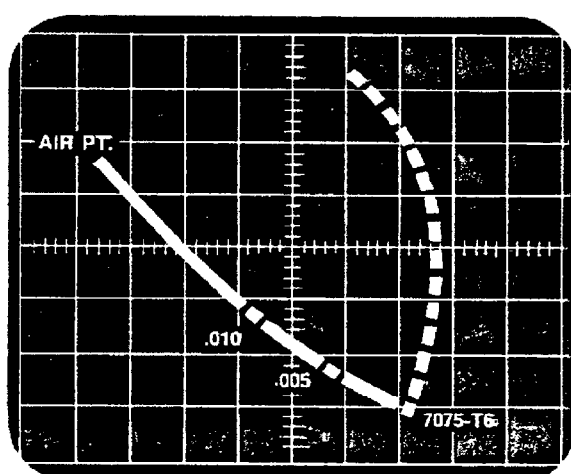
Metals Sorting (Conductivity)



Corrosion Thinning



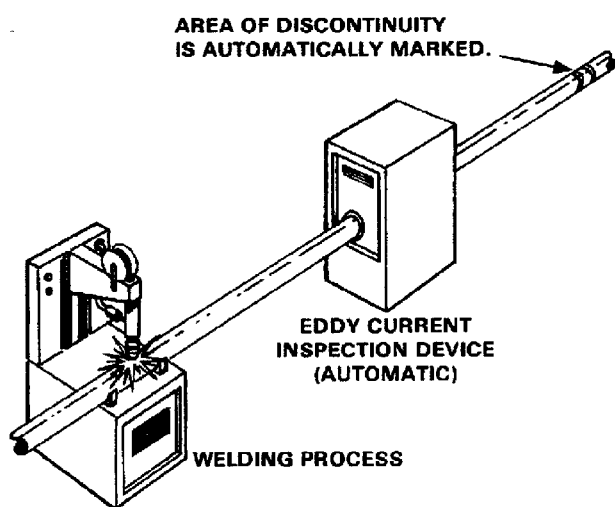
Flaw Detection



Coating Thickness

Typical CRT Displays for Eddy Current Testing

11-14



Typical Eddy Current Inspection Arrangement

Acoustic Emission Testing (AET)

Atomic movements leading to cracking are accompanied by sound bursts which may be detected by suitable microphones (piezoelectric ceramic elements). These sounds are emitted in all directions and may be detected from any surface of the vessel. By monitoring the emissions, the weld quality may be assessed during welding and during cooling. Weldments having incomplete joint penetration, incomplete fusion, cracking, porosity, or various imperfections can be detected, the the regions emitting the sound can be located by triangulation from several sensors (using a computer).

After the weldment has cooled, the sounds will cease, and a stimulus (mechanical loading or thermal stress) must be applied to cause further acoustic emission. Stress exceeding the maximum stress previously experienced by the metal causes plastic deformation at the tip of any crack and a tell-tale acoustic burst is emitted. If the discontinuities in the weldment are not affected by loading, they will not be active emitters, and the part will be recognized as structurally "sound" (soundless).

Acoustic emission testing can be a valuable adjunct to hydrostatic pressure testing. Acoustic emissions from a growing crack increase in

number and intensity as a function of the applied variable (displacement, load, pressure, or time). Instantaneous interpretation and location of the source can permit a repair to be made before the vessel is harmed by rupturing.

Acoustic emission is also used to monitor in-process welding on production lines and to monitor critical weldments in service.

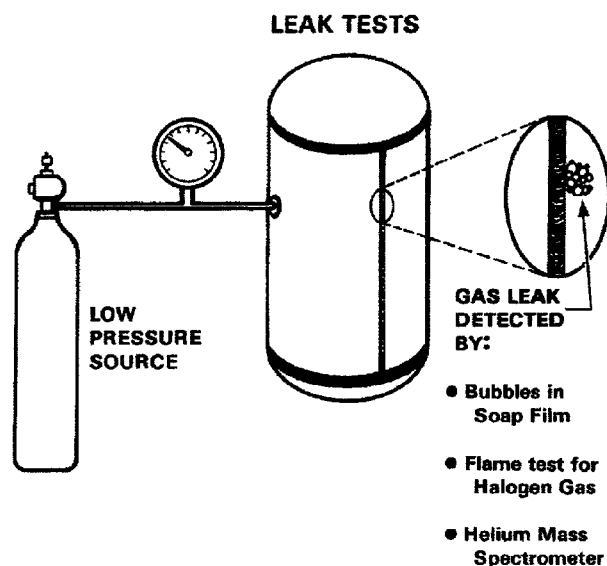
Leak Tests (LT)

One further indignity may be inflicted upon a well examined weldment: a test for leaks.

Test methods may be as unsophisticated as the pneumatic or gas and soap bubble test. By lightly pressurizing the component and immersing the vessel in water or brushing a soap film over the surface, the formation of bubbles can be observed at any leak.

Open tanks are frequently tested by filling them with water containing fluorescein, which permits ready detection of any seepage under ultraviolet illumination. The hydrostatic (or head) pressure causes the fluorescein to escape through any leaks and be detected.

Another leak test applied to storage tanks (principally floor joints) is referred to as the vacuum box test. Here, the weld surface is



covered with a soap solution and a transparent box with soft rubber seal is placed over a portion of the weld length. Using a vacuum pump or compressed air, a vacuum is created in the box and any leaks will be indicated by the presence of bubbles.

The leak test may use an organic halide gas on one side of the vessel and a halide torch on the other. The torch flame changes color in the presence of halogens.

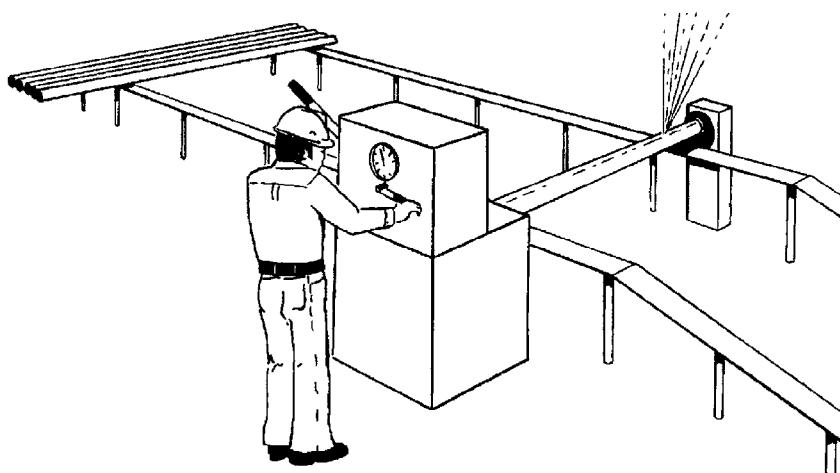
The ultimate leak test is considered to be the helium leak test which uses helium as a tracer gas. Due to their extremely small size, helium atoms pass through even the smallest leaks. These very small leaks are then detected using special instruments capable of sensing any leakage of the helium gas. (helium spectrometer leak testing)

Details of the more complex tests are available from manufacturers of the equipment used. Once again, the rules for acceptance and rejection must be spelled out in the specifications.

Pressure Tests

A pressure test is one of the family of tests referred to as proof tests (PRT). A pressure test is the "final test" which some of the weldments previously examined must pass to earn a certificate of fitness. Details of how the pressure test is to be conducted should be given in the documents governing each assembly or subassembly.

Here is an important word of caution: In any hydrostatic test of a closed vessel, make certain that the technicians have vented all air trapped within the container before permitting the pressurization to begin. Liquids are essentially noncompressible. If the vessel is entirely filled with liquid, should rupture begin, the first leakage will reduce the pressure dramatically and the fracture will stop. However, if air has been



Complete Sampling Is Commonly Applied To Proof Tests or Final Inspection

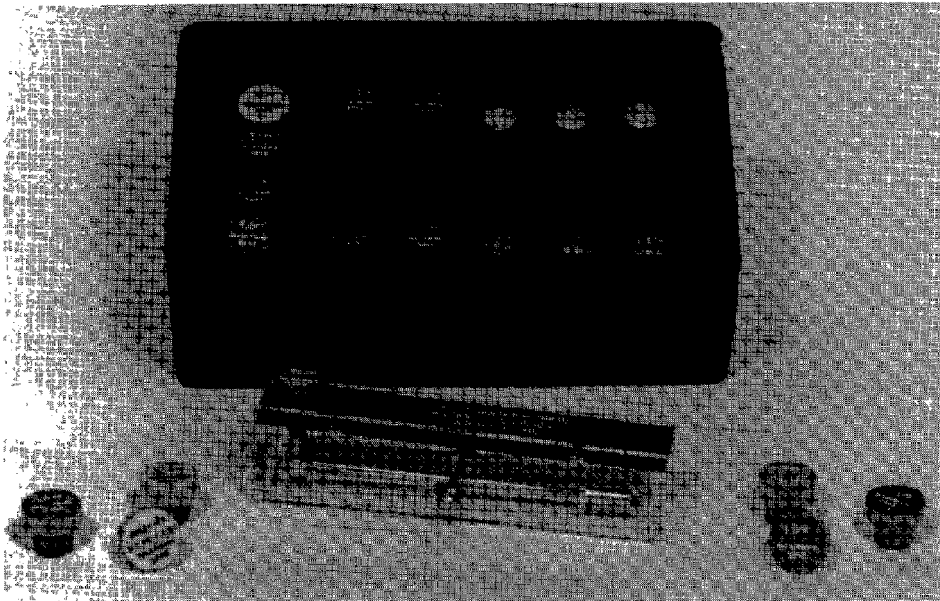
trapped, its energy of compression will continue to extend the fracture explosively, with great damage and danger to observers. It is also very important to remember to vent any vessel after the hydrostatic test is completed. When draining test fluids, a vacuum may be created which may be adequate to damage the component.

Magnetic Test for Delta Ferrite

Delta ferrite is an effective crack deterrent in austenitic stainless steels. This phase is magnetic, whereas austenite is nonmagnetic. That property is now used to measure the amount of ferrite in the weld metal, which marks a major advance for weld examination. The alternate methods of measurement are laborious and inaccurate:

- Microscopic examination checks one tiny spot at a time which may not be typical, since ferrite is not distributed uniformly; etching the phase to identify it may distort its size.
- Computations based on chemical composition ignore the treatment effects and are subject to analytical errors.

The American Welding Society recommends that delta ferrite be reported in Ferrite Numbers, a standard measurement based on comparison with



FERRITE INDICATOR (SEVERN GAGE)

magnetic chips obtained from the U. S. National Bureau of Standards (NBS). The testing method is explained in AWS A4.2, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*.

Magnetic instruments such as the Magna-Gage and other commercial devices are calibrated by measuring their response to the NBS wafers. The same instrument is then used to measure the desired weld metal.

The observed Ferrite Number (FN) is approximately equal to the percent ferrite that would be found by other techniques, but it has the advantage of being reproducible in any laboratory around the world.

The NBS wafers have been assigned Ferrite Numbers depending on their thickness, which determines their magnetic response. A calibration curve is drawn showing the instrument readings plotted against FN. The curve is then used to interpret readings taken on actual weld specimens.

In the course of his inspection work, the welding inspector will no doubt find some contracts specifying delta ferrite in Ferrite Numbers and some specifying percent ferrite. He

should endeavor to have all readings measured and reported in Ferrite Numbers, because they can be verified by the NBS standards. However, FN readings could be labeled "percent", with less error than would arise from a micrographic count or from estimating the ferrite using the reported chemical analysis.

Note one difference in the ferrite indications given by the Severn gage. This is a balance beam instrument which pre-

sents the opposite ends of a bar magnet simultaneously to a known ferrite standard and to the unknown ferrite content of the weld. The operator notes which of the two metals is magnetically stronger. The test tells only that the weld had more ferrite or less ferrite than the standard. There is no indication of how much the two differed. Other instruments indicate the actual Ferrite Number of the weld, but the Severn gage merely gives an upper or lower limit to the FN.

That will be sufficient for most inspections if the contract calls for, for example, "over 4 FN," or "over 4 percent ferrite." All portions of that weld should pull the magnet away from the 4 FN button. If the contract requires "4 to 10 FN," the welding inspector must also search with a 10 FN button, which should always pull the magnet away from the weld.

If delta ferrite prevents cracks, why is there concern about an upper limit to the Ferrite Number? The answer: High ferrite content increases the probability of forming a brittle sigma phase after heat treatment. Sigma is undesirable in stainless steel welds.

Qualification of Nondestructive Examination Personnel

Nondestructive examination personnel also require qualification and certification. Nondestructive tests are based on indirect indications: typically, the density of a photographic film is interpreted to indicate a discontinuity at the center of the weld, and an adhering line of magnetized iron powder is interpreted to reveal a subsurface crack. These may not be direct revelations of the supposed discontinuity. Some of them may be artifacts extraneous to the subject. The individual interpreting such information must be qualified to accurately interpret test results.

The qualification procedure usually specified is that recommended by the American Society for Nondestructive Testing's (ASNT) Recommended Practice No. SNT-TC-1A. Since this is considered a recommended practice, it only has relevance when a company develops a quality control manual which refers to these recommendations.

This standard provides for three levels of competence and responsibility, as shown in the following table:

NDT Level I permits the individual to operate NDT equipment and interpret results under direct supervision of a person certified for Level II or Level III. NDT Level II clears the individual for

all testing and interpretation of indications. NDT Level III qualifies the individual to conduct qualification examinations of persons applying for Levels I and II.

Notice that individuals are not permitted to examine AWS D1.1 Code weldments by NDE methods other than visual unless they hold SNT-TC-1A certification papers. Also, do not mistakenly assume that a Level III individual (able to train and examine personnel at the other levels) would be permitted to make these tests. That person would not be acceptable without Level I or Level II qualification in addition to his Level III certification.

Under the ASME Code rules, the Authorized Inspector verifies the certification of NDE personnel in accordance with the applicable ASME requirements, which most likely reference SNT-TC-1A. When the Authorized Inspector questions the performance of an NDE technician, he has the further authority to audit the program and require requalification.

Summary

Although the CWI will not necessarily be qualified to perform nondestructive examinations other than visual, it is important that that individual at least understands the basic principles of the more common methods. This will assist in developing an understanding of the results reported by those performing the necessary tests.

In addition to review of nondestructive examination results, the CWI may also be responsible for determining if NDE technicians are properly qualified to perform various tests in accordance with contract requirements.

BRIEF ABSTRACT OF SNT-TC-1A LEVELS OF QUALIFICATION	
NDT LEVEL I:	An individual qualified to perform specific calibrations, specific tests, and specific evaluations according to written instructions and to record the results; the necessary guidance or supervision from a certified NDT Level II or III individual
NDT LEVEL II:	An individual qualified to set up and calibrate equipment and to interpret and evaluate results with respect to applicable codes, standards, and specifications; responsible for on-the-job training and guidance of trainees and NDT Level I personnel; prepares written instructions, and organizes and reports NDT investigations.
NDT LEVEL III:	An individual capable of and responsible for establishing techniques; interpreting codes, standards, and specifications; designating the particular test method and technique to be used; responsible for a complete NDT operation; establishes techniques and assists the design engineer in establishing acceptance criteria where none are otherwise available; responsible for the training and examination of NDT Level I and Level II personnel for certification.

REVIEW CHAPTER 11 NONDESTRUCTIVE EXAMINATION

- Q11-1** Which of the following nondestructive examination methods do not usually require electricity?
- a. eddy current
 - b. visible dye penetrant
 - c. visual
 - d. a and b above
 - e. b and c above
- Q11-2** Which of the following nondestructive examination methods is limited to the detection of surface discontinuities?
- a. visual
 - b. penetrant
 - c. magnetic particle
 - d. all of the above
 - e. none of the above
- Q11-3** To be most effective, visual inspection should be performed:
- a. before welding.
 - b. during welding.
 - c. after welding.
 - d. all of the above
 - e. none of the above
- Q11-4** The time during which the penetrant remains on the surface of the part to allow it to be drawn into any discontinuities is called:
- a. waiting time.
 - b. penetrating time.
 - c. soak time.
 - d. dwell time.
 - e. none of the above

- Q11-5** Which type of magnetizing current provides the best combination of penetrationability and particle mobility?
- a. AC
 - b. DC
 - c. half-wave rectified DC
 - d. b and c above
 - e. all of the above
- Q11-6** What NDE method will most likely reveal subsurface porosity?
- a. PT
 - b. MT
 - c. RT
 - d. UT
 - e. all of the above
- Q11-7** Which of the following statements is correct for a radiographic test?
- a. A reduction in thickness will produce a light image on the film.
 - b. A low-density discontinuity will produce a light image on the film.
 - c. A high-density discontinuity will produce a light image on the film.
 - d. a and b above
 - e. b and c above
- Q11-8** Which of the following discontinuities will not likely be revealed using RT?
- a. crack
 - b. incomplete fusion
 - c. undercut
 - d. lamination
 - e. none of the above
- Q11-9** What device is used during radiography to indicate the acquired sensitivity of a radiograph?
- a. rate meter
 - b. dosimeter
 - c. lead screen
 - d. penetrameter
 - e. none of the above

11-20

Q11-10 Which nondestructive examination method utilizes sound energy as a probing medium?

- a. VT
- b. RT
- c. UT
- d. PT
- e. ET

Q11-11 The process whereby the ultrasonic indications are related to physical distances in a test standard is referred to as:

- a. setup
- b. calibration
- c. standardization
- d. synchronization
- e. none of the above

Q11-12 A test probe containing an alternating current coil is used for which NDE method?

- a. RT
- b. UT
- c. ET
- d. MT
- e. c & d above

Q11-13 Changes in electrical conductivity can be measured using which NDE method?

- a. ET
- b. RT
- c. MT
- d. UT
- e. none of the above

Q11-14 Which of the following NDE methods are suitable for detecting surface cracks?

- a. RT
- b. VT
- c. ET
- d. PT
- e. all of the above

Q11-15 What NDE method is most likely to reveal internal laminations in a rolled plate?

- a. RT
- b. UT
- c. ET
- d. MT
- e. none of the above

Q11-16 PT is limited to the detection of those discontinuities which are?

- a. near the test object surface
- b. open to the test object surface
- c. clean and open to the test object surface
- d. all of the above
- e. none of the above

Q11-17 Visible dye penetrant indications:

- a. must be observed under a black light
- b. don't have to be observed under a black light, but are more sensitive if they are
- c. must be observed under ultraviolet light
- d. must be observed under white light
- e. none of the above

Q11-18 Penetrant can be applied by:

- a. brushing
- b. spraying
- c. dipping
- d. all of the above
- e. none of the above

Q11-19 Fluorescent penetrants are generally more sensitive than visible dye penetrants because:

- a. they can flow into smaller cracks
- b. fluorescent indications are better seen by the human eye
- c. they are subject to greater capillary action
- d. a and c above
- e. b and c above

11-22

Q11-20 Which of the following cause decreased sensitivity in PT?

- a. too heavy application of the developer
- b. oily or greasy test object
- c. improper penetrant removal
- d. all of the above
- e. none of the above

Q11-21 PT is limited to test objects which:

- a. are metallic
- b. are porous
- c. are magnetic
- d. are nonporous
- e. have subsurface discontinuities

Q11-22 MT will discover:

- a. surface discontinuities
- b. slightly subsurface discontinuities
- c. underbead cracking
- d. a and b above
- e. all of the above

Q11-23 MT is most sensitive to those discontinuities which are:

- a. within 45° of perpendicular to the lines of flux
- b. within 45° of parallel to the lines of flux
- c. perpendicular to the lines of flux
- d. parallel to the lines of flux
- e. none of the above

Q11-24 MT is limited to test objects which:

- a. are metallic
- b. are porous
- c. are ferromagnetic
- d. are nonporous
- e. have subsurface discontinuities

Q11-25 UT is most sensitive to those discontinuities which are:

- a. within 45° of perpendicular to the sound waves
- b. within 45° of parallel to the sound waves
- c. perpendicular to the sound waves
- d. parallel to the sound waves
- e. none of the above

Q11-26 UT uses frequencies:

- a. below the range of human hearing
- b. within the range of human hearing
- c. above the range of human hearing
- d. beside the range of human hearing
- e. none of the above

Q11-27 In UT the horizontal axis of the CRT screen gives information about:

- a. the distance the sound has traveled in the part
- b. the amount of sound energy reflected
- c. the type of discontinuity
- d. discontinuity orientation
- e. discontinuity cause

Q11-28 RT shows areas of lower density as:

- a. dark regions on the film
- b. light regions on the film
- c. light or dark regions on the film
- d. all of the above
- e. none of the above

Q11-29 RT shows areas of less thickness as:

- a. dark regions on the film
- b. light regions on the film
- c. light or dark regions on the film
- d. all of the above
- e. none of the above

Q11-30 RT shows areas of increased transmission as:

- a. dark regions on the film
- b. light regions on the film
- c. light or dark regions on the film
- d. all of the above
- e. none of the above

11-24

Q11-31 Tungsten inclusions generally appear in RT as:

- a. dark regions on the film
- b. light regions on the film
- c. light or dark regions on the film
- d. all of the above
- e. none of the above

Q11-32 Cracks generally appear in RT as:

- a. dark lines on the film
- b. light lines on the film
- c. light or dark lines on the film
- d. all of the above
- e. none of the above

Q11-33 Weld reinforcement generally appears as:

- a. dark regions on the film
- b. light regions on the film
- c. light or dark regions on the film
- d. all of the above
- e. none of the above

Q11-34 Porosity generally appears in RT as:

- a. dark regions on the film
- b. light regions on the film
- c. light or dark regions on the film
- d. all of the above
- e. none of the above

Q11-35 Shallow surface cracks can best be detected in 308 stainless by:

- a. UT
- b. MT
- c. RT
- d. PT
- e. all of the above

Q11-36 Underbead cracks can best be detected by:

- a. ET
- b. MT
- c. UT
- d. PT
- e. all of the above

Q11-37 Porosity in ESW can best be detected by:

- a. UT
- b. MT
- c. RT
- d. PT
- e. all of the above

Q11-38 The vertical axis of the UT CRT screen represents:

- a. distance
- b. time
- c. reflector size
- d. none of the above
- e. all of the above

Q11-39 What NDE method(s) rely on the transmission of sound energy through the test object?

- a. RT
- b. UT
- c. AET
- d. a and b above
- e. b and c above

Q11-40 What NDE method(s) often rely on the application of a hydrostatic pressure to a vessel?

- a. pressure tests
- b. leak tests
- c. proof tests
- d. all of the above
- e. none of the above

11-26

Q11-41 What test below is applied to determine the metallurgical effects of welding on austenitic stainless steels?

- a. RT
- b. PRT
- c. ferrite test
- d. UT
- e. PT

Q11-42 Application of a vacuum box to the inside surface of a steel storage tank is one form of which test below?

- a. VT
- b. PRT
- c. LT
- d. all of the above
- e. none of the above

Q11-43 FN is a unit of measurement with which test below?

- a. RT
- b. PRT
- c. ferrite test
- d. UT
- e. PT

Q11-44 NDE personnel are normally qualified in accordance with

- a. ASME Section V
- b. AWS D1.1
- c. ANSI SNT-TC-1A
- d. ASNT SNT-TC-1A
- e. ASME SNT-TC-1A