REMR TECHNICAL NOTE CS-ES-1.4

NONDESTRUCTIVE TESTING METHODS FOR METAL STRUCTURES

PURPOSE: To provide information on nondestructive testing methods for metal structures that are readily available from most commercial testing laboratories.

APPLICATION: The nondestructive testing methods described in this technical note can be used to inspect metal structures, parts, or components for surface and subsurface defects.

APPLICABLE CODES AND STANDARDS:

AWS Structural Welding Code Bl.10
Ultrasonic, ASTM E 114, 164, and 797
Dye Penetrant, ASTM E 165
Magnetic Particle, ASTM E 709
Radiography, ASTM E 94 and E 1032

ADVANTAGE: Nondestructive testing is ideally suited for the inspection of welds and can be used to monitor the performance of welders, as well as to determine the quality of welds and metal components.

DESCRIPTION: This technical note covers the five most common nondestructive testing methods used in the construction industry to detect surface and internal discontinuities in welds and fabricated components: visual, penetrants, magnetic particle, ultrasonic, and radiographic testing.

a. Visual: Visual inspection of a weld can be used to determine if the weld was made properly. Unacceptable weld profiles, insufficient throat, or excessive concavity can reduce the strength of a weld by producing undesirable stress concentrations. Alignment, distortion, arc strikes, and the general condition of the weld can be observed in addition to weld profiles. The person performing this inspection should have a magnifying glass, flashlight, and "fillet" measuring gage.

b. Penetrants: Penetrant inspection methods are used for inspecting almost any nonporous material for defects that are open to the surface. Surface defects that can be found are all types of cracks in connection with welding, grinding, fatigue, etc. Penetrant methods are restricted to the location of surface defects; therefore, cleanliness is of the utmost importance. Penetrant inspection consists normally of four steps (Figure 1): application of the penetrant, removal of excessive penetrant from the surface, application of a developer, and inspection. The two main groups of penetrants are visible dyes and fluorescent penetrants.

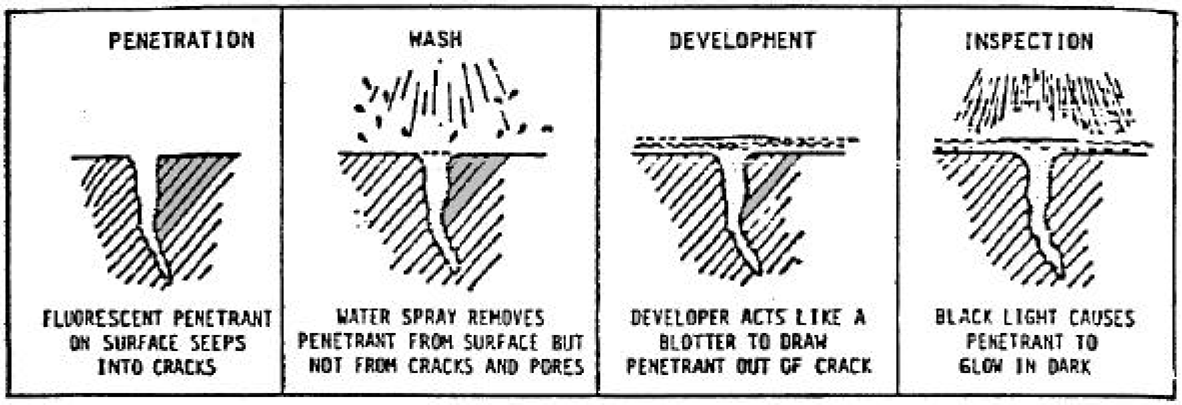

Figure 1. Major steps of fluorescent penetrant inspection (reprinted from AF Study Guide ABR 53630-201)

1. The advantages of the visible dye penetrant method are that it provides fast, on-the-spot inspection and its initial cost is relatively low. A white or blank surface indicates freedom from cracks or other defects that are open to the surface. Disadvantages are that it is not practical on rough surfaces and it detects only defects open to the surface.

2. The advantages of the fluorescent penetrant method are that it can be used on rough surfaces and it is much more sensitive than dye penetrants. Disadvantages are that a black light and hood are required (unless testing is performed at night) and only defects open to the surface are detected.

c. <u>Magnetic particle:</u> Magnetic particle inspection will indicate surface or near-surface defects in ferromagnetic materials such as iron and steel. A magnetic current is introduced into the area to be inspected, and iron oxide powder is dusted on the area. The induced magnetic field will be distorted if there is a discontinuity such as a crack on or near the surface (Figure 2). A leakage of this field creates poles that attract the iron oxide powder dusted on the area. A sharp line indicates a surface discontinuity. When the discontinuity is below the surface, the field is weaker and less concentrated; therefore, the powder indication on the surface will be broad and fuzzy.

1. A principal limitation of the magnetic particle method is that it applies only to magnetic materials and is not suited for small deep-seated defects. The deeper the defect is below the surface, the larger it must be to be detected. With magnetic particle testing, the surface to be inspected must be accessible. This means shafts or other equipment cannot be inspected without removing pressed wheels, pulleys, or bearing housing.

2. The advantages of magnetic particle inspection are that it is a positive method of finding all cracks at the surface, the equipment is portable, and the method is flexible.

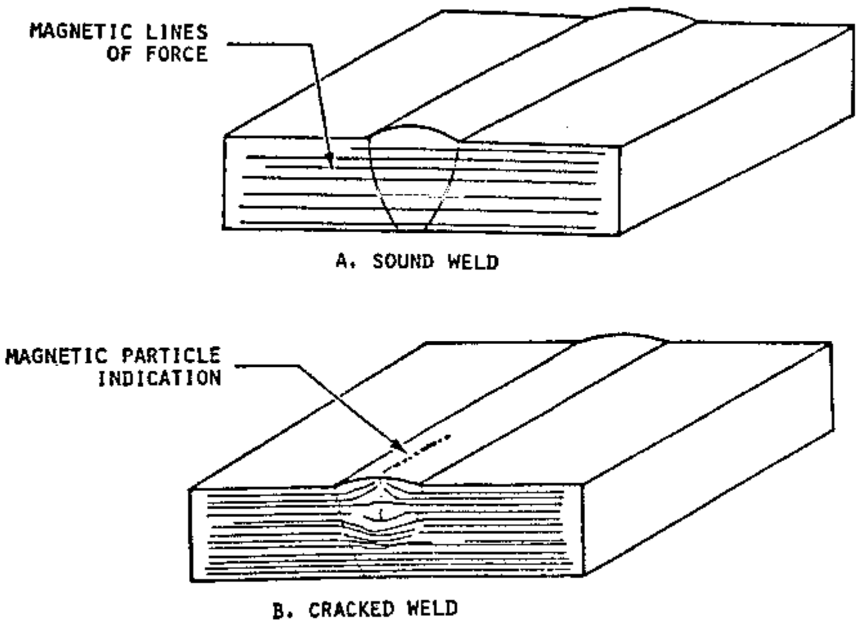

Figure 2. Disruption of magnetic field by weld-metal defect (reprinted from Technical Manual 5-805-7, "Welding Design, Procedures and Inspection," Headquarters, Department of the Army, 1968)

d. Ultrasonic: Ultrasonic inspection uses a beam of high-frequency sound, in the range of 1 to 5 MHz, to inspect a wide range of thicknesses and materials. The ultrasonic unit produces electrical pulses that are fed to a handheld transducer or search unit, where the electrical energy is converted to mechanical energy. A couplant, which can be oil, grease, water, etc., is placed on the area being inspected; the transducer is then placed on the couplant in contact with the metal. The mechanical energy emitted from the transducer is similar to a beam of light from a flashlight. The soundwave is emitted as bursts or pulses of energy vibrations. These vibrations travel into the area being inspected until they strike or are interrupted by a crack, inclusion, or other discontinuity or by the far side of the material. When a discontinuity is encountered, some of the sound vibrations are reflected to the transducer. The larger the discontinuity (crack, porosity, slag inclusion, etc.), the larger the amount of energy that will be reflected to the transducer. The transducer converts the returning vibrations into electrical impulses that are amplified and appear on the screen of a cathode-ray tube (CRT) as indications. The initial pulse on the screen represents the contact face or the testing surfaces (A, Figure 3). The flaw (B) reflects some sound, and the rear surface (C) reflects more sound. The presentation on the CRT displays the location in the thickness and relative size of the flaw. The distance between A and C is representative of the material thickness; therefore, the distance that the flaw is below the surface can be fairly accurately measured. The size of the flaw determines the height of the indication B. A calibration standard is required to accurately measure defect size.

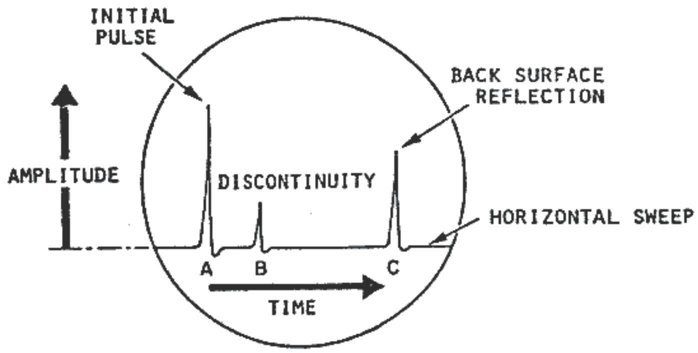

Figure 3. A scan presentation on CRT (reprinted from MIL HDBK 333 (USAF), "Handbook for Standardization of Nondestructive Testing Methods," Department of Defense, 1974)

1. A limitation of the ultrasonic inspection method is that a permanent record is difficult to obtain during field inspection. A picture of the CRT and written reports of the inspection results are sometimes difficult to correlate. Rough surfaces make transducer contact difficult and sometimes impossible. A couplant must always be used to eliminate compressible air and fill the voids and irregularities on the test surface. Calibration standards are usually required to calibrate the instrument and evaluate sizes of defects.

2. Ultrasonic inspection allows the inspector to inspect almost any material quickly with minimum restriction to size, shape, or thickness. With a variety of plastic wedge angles that can be used with transducers, sound energy can be transmitted into a part at different angles for complete inspection.

e. Radiography: Radiography includes X-ray and gamma ray inspection. X-ray is radiation generated from an X-ray tube, whereas gamma is a radioisotope, usually iridium 192. The radiation from these sources is of such a short wavelength that it can penetrate materials to disclose the presence of flaws and imperfections in the interior of metals and weldments. The radiation intensity is affected by flaws and material differences. The radiation emitted from either of these sources is passed through, absorbed, or scattered in the metal. For example, if there is a slag inclusion or porosity as the radiation passes through a weld, the void results in the reduction of the total thickness of the weld figure. This reduction in metal allows more radiation to pass through the section containing the void than through the surrounding metal. Variations in the radiation beam are recorded as an image on a film. A dark spot, corresponding to the projected position of the void, will appear on the film when it is developed. Thus, a radiograph is a kind of shadow picture: the darker regions on the film represent the more penetrable parts of the weld; the lighter regions, the more opaque.

1. A limitation to radiography is the radiation hazard. The work area near the source must be cleared when X-ray gamma sources are used. Companies that perform radiography use two or three people for safety reasons. While one inspector is performing the radiography, another is developing the film, and the third, if used, is monitoring the area. The X-ray or gamma source, portable darkroom, film, and development solutions make radiography an expensive process.

2. Radiography will produce a permanent record on film that can be kept on file. Gamma or isotope radiography is used much more than X-radiography because of the higher penetrating power and its portability.