PART 4 – ADDITIONAL INVESTIGATIONS

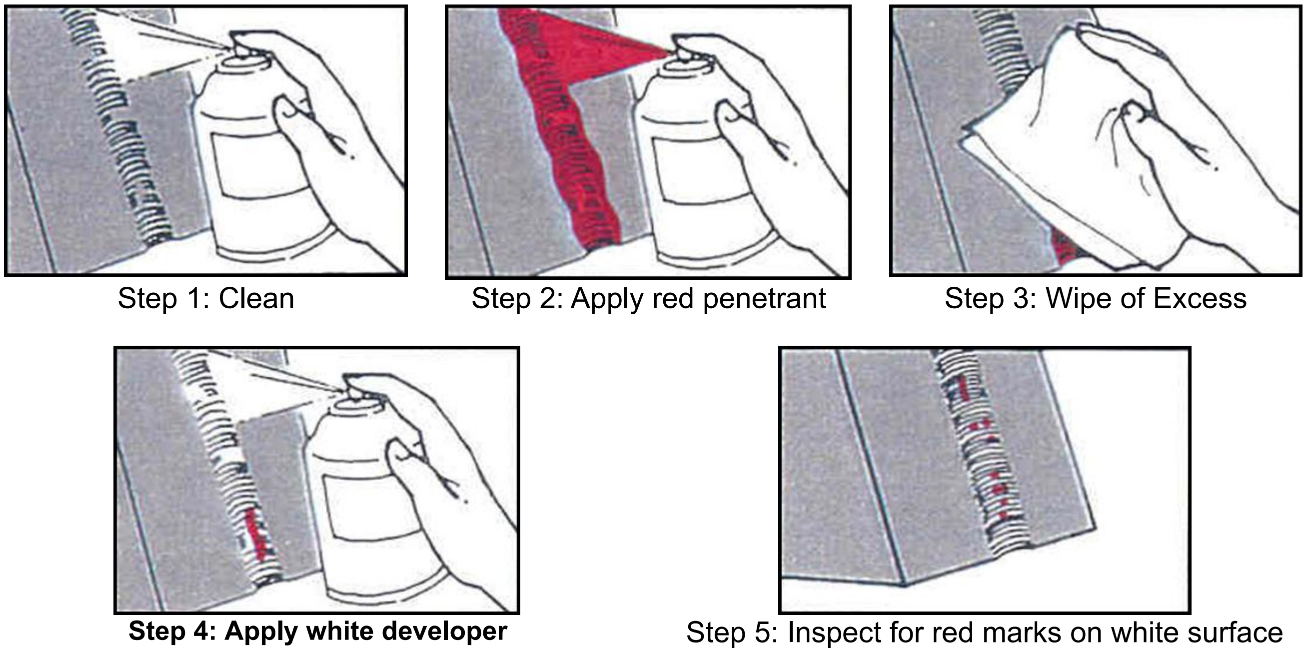

Figure 4.1.1.1 Steps Required for Applying Liquid Penetrant

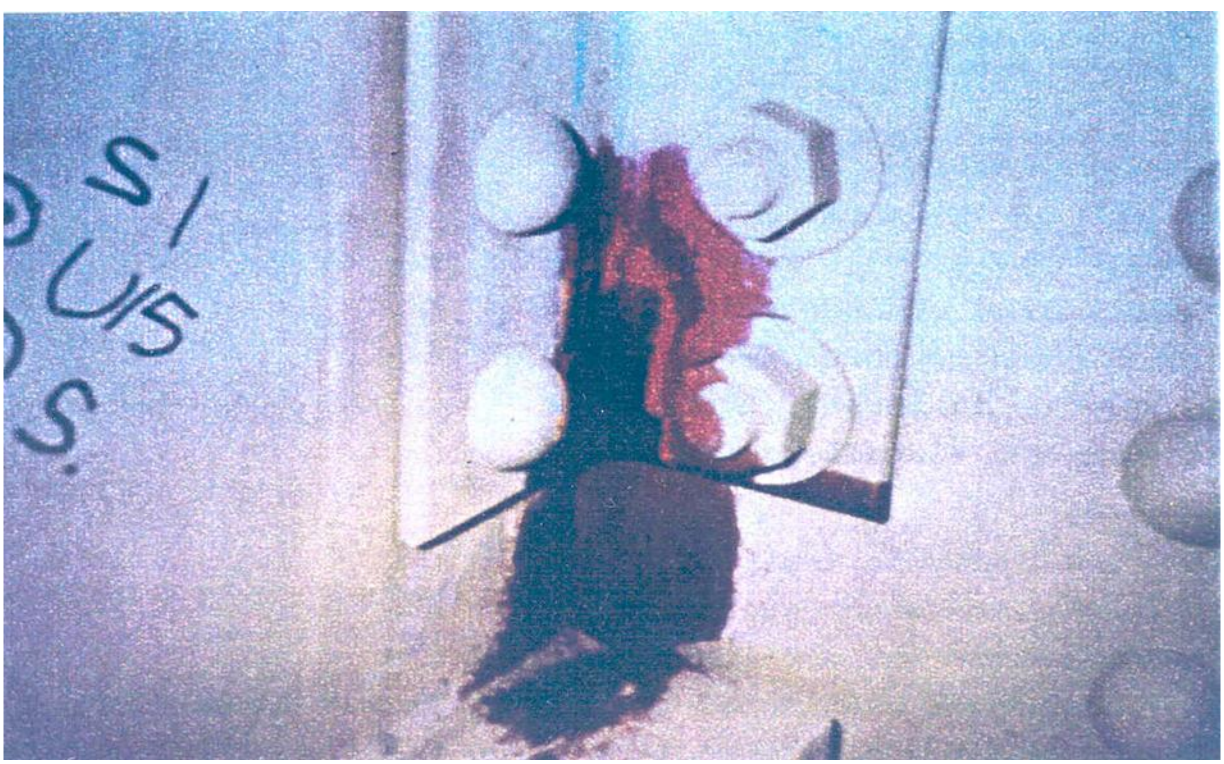

Figure 4.1.1.2 Metal Surface After Liquid Penetrant Application

PART 4 – ADDITIONAL INVESTIGATIONS

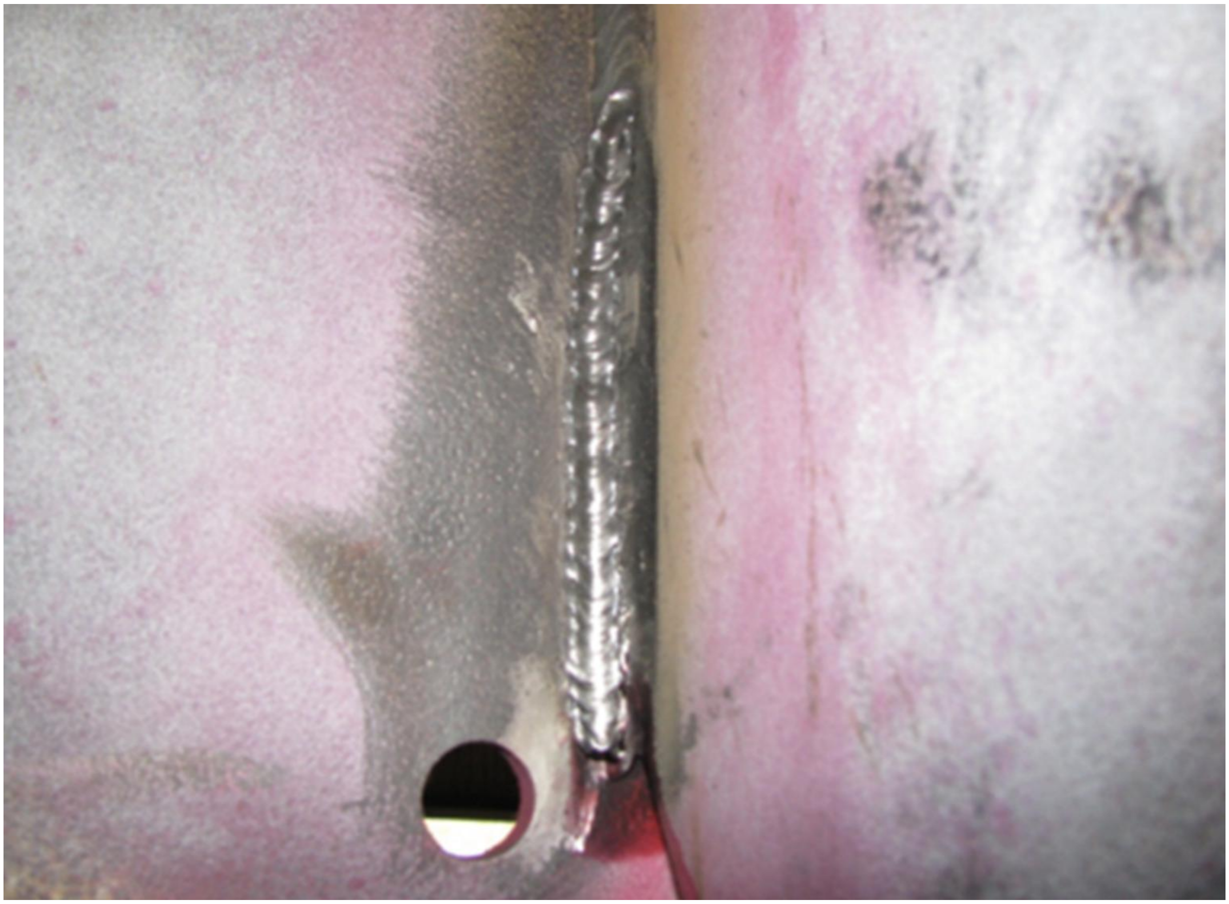

Figure 4.1.1.3 Surface after developer has been applied. A crack was detected by the small thin red line (bottom of the weld)

Advantages

- Highly portable
- Relatively inexpensive
- Can be applied to a wide variety of non-porous surfaces
- Rapid method of inspection
- Results can be recorded photographically
- No special equipment required
- Results are visually apparent

Disadvantages

- Does not indicate depth of flaw

- Surface must be accessible
- Cannot detect any sub-surface defects
- Test site must be cleaned thoroughly before inspection
- Post cleaning may be necessary

References:

- See References 8-11

4.1.1.2 Magnetic Particle

Magnetic Particle Testing is used to detect surface and near surface defects.

When a ferromagnetic material is subjected to a magnetic field, magnetic flux lines are generated in specific directions, depending on the placement of the contact electrodes or magnetic poles. When a defect within the field lies generally at right angles to the flux lines, the field will be distorted and some of the magnetic flux will leak out of the steel at the defect. Fine magnetic particles (low retentivity iron powder) distributed over the surface are attracted by the leakage field and held magnetically to form an outline of the defect.

The area to be examined is magnetized by two current carrying copper prods held against the surface of the component, a short distance apart to produce a circular magnetic field. As only defects which are perpendicular to the magnetic flux lines, can be detected, the prods must be moved about and re-positioned to ensure that all defects are located regardless of orientation.

Both AC and DC electric current is suitable for magnetizing steel components. Surface defects are most readily detected with AC magnetization. DC magnetization provides greater penetration for detection of subsurface defects.

Electromagnetic yokes produce suitable magnetic fields and are highly portable.

Figure 4.1.1.4 shows units used for producing a magnetic field and Figure 4.1.1.5 illustrates how the yokes are used in conjunction with particle application for inspection.

PART 4 – ADDITIONAL INVESTIGATIONS

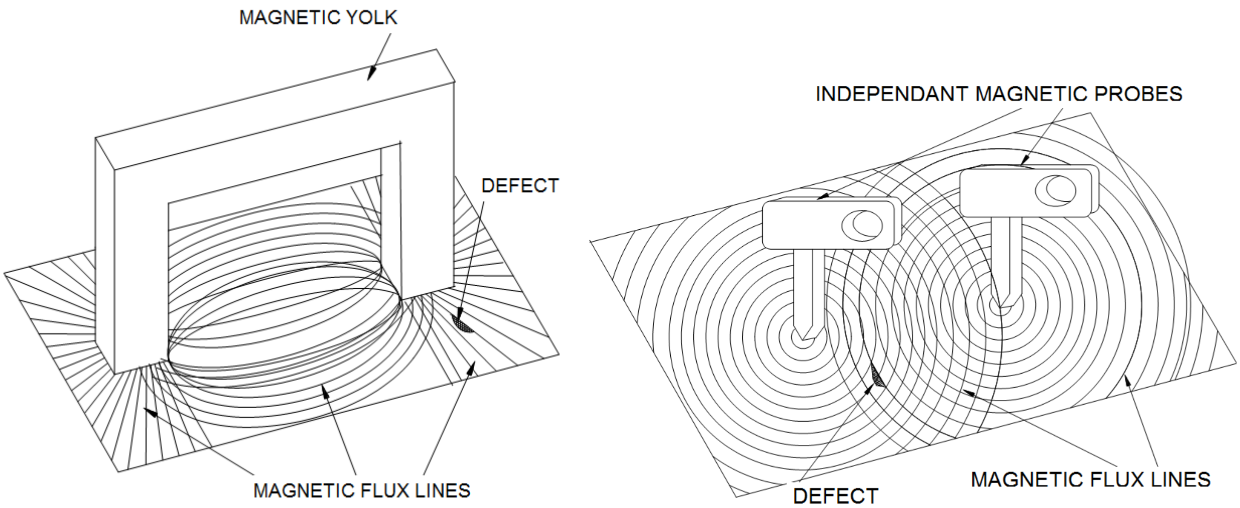

Figure 4.1.1.4 Typical units used for generating magnetic fields to locate an defects.

Figure 4.1.1.5 Typical Magnetic Particle Application and Field Generator

Advantages

- Portable and inexpensive;
- Can detect fine and shallow surface cracks;

PART 4 – ADDITIONAL INVESTIGATIONS

- Fast and relatively simple to apply;
- Few limitations on size and shape of parts or structures;
- Surface cleanliness and cleaning methods not as important as for liquid penetrant method.

Disadvantages

- Surfaces must be reasonably smooth to avoid non-relevant indications;
- Requires removal of surface materials which may interfere with the ability to magnetize the area. (Generally, the area should be cleaned of debris and loose materials. Non-conductive coatings must be removed where the prods contact the metal.);
- Only detects surface defects with certainty, does not indicate depth of cracks and defects.
- Some sub-surface defects are detectable but indications are diffused;
- Direction and strength of the magnetic field is critical, flux lines should be normal to the plane of a defect;
- Prod method of magnetization can cause arc burns and possible cracks;
- Demagnetization is necessary when magnetic particles may interfere with working metal surfaces, threads on bolts or subsequent painting operations;
- Can only be applied to accessible surfaces;

References

- See References 8, 12-14

4.1.1.3 Ultrasonic Testing

Ultrasonic testing is a method in which high frequency sound waves are introduced into a material for the detection of surface and internal defects. They pass through the material and are reflected at interfaces or boundaries such as flaws such as cracks, slag inclusions, porosity etc., or the back surface of the material. The reflected waves returning to the source can be displayed as pulses or signals on the screen of a cathode ray tube. The pulses or signals relate to the transit time of the sound. The travel time of the returning pulses is a measure of the distance to the interface of the defect.

The ultrasonic method is used to detect cracks and various other types of planar defects in wrought materials, to examining welds in fabricated components for cracks, slag inclusions and porosity, and for measuring residual wall thickness of corroded components.

The ultrasonic system is comprised of a high frequency pulse generator, transducer, receiving amplifier and CRT screen. These components allow for detection and location of defects. By various scanning movements in the area of a defect, orientation, size, shape and nature can be determined through interpretation of the reflected pulses displayed on the screen of the instrument. Ultrasonic systems can detect discontinuities that are larger than one half of the wavelength of the signal. A system operating at 5MHz will detect defects larger than about 0.5mm.

A schematic of ultrasonic testing is shown in Figure 4.1.1.6 and the application of the instrument in Figure 4.1.1.7.

PART 4 – ADDITIONAL INVESTIGATIONS

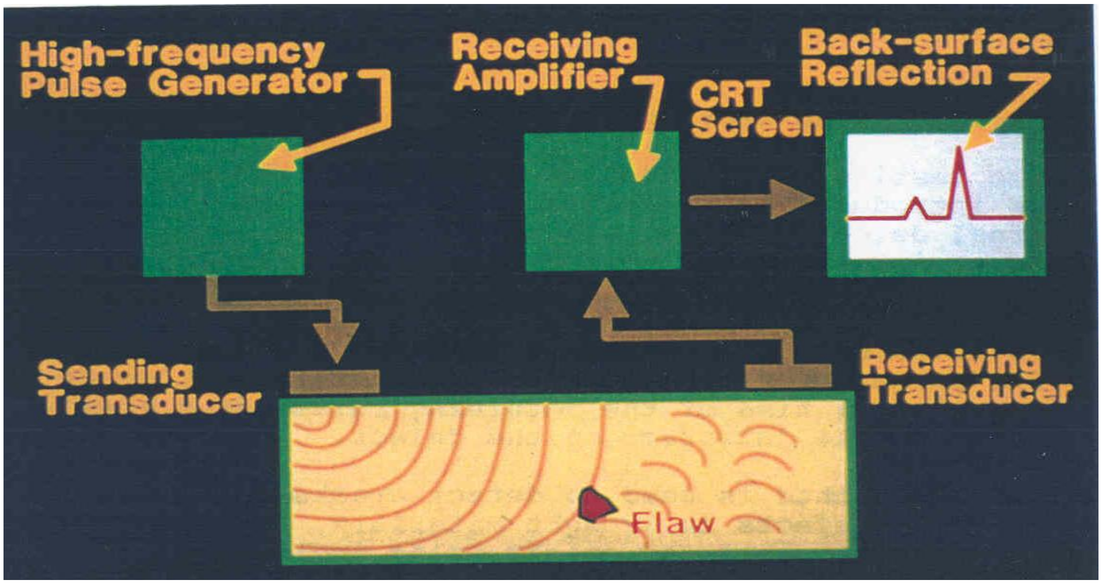

Figure 4.1.1.6 Schematic of Ultrasonic Testing Equipment

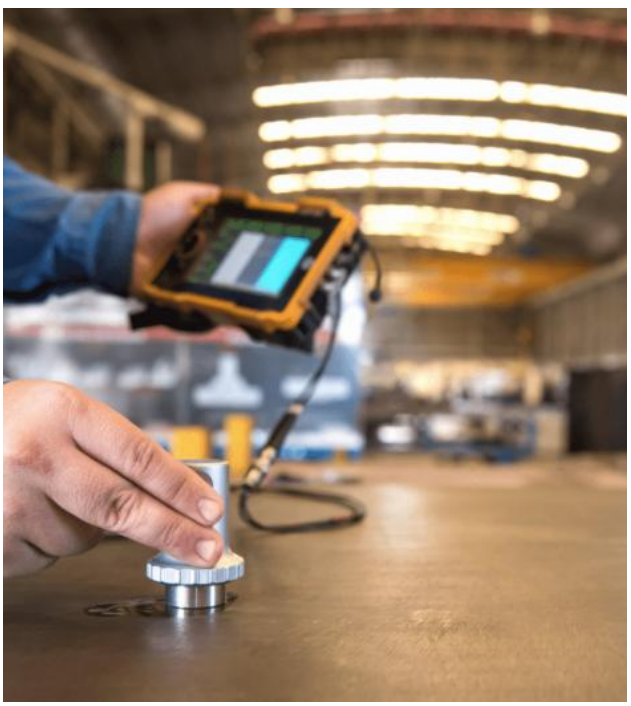

Figure 4.1.1.7 Application of Ultrasonic Testing Equipment

Advantages

- Detects the depth and location of cracks and planar defects;
- Very sensitive and can detect small defects such as inclusions;
- With adjustments in procedure (angle-beam method and contact pulse reflection) can detect internal defects and fatigue cracks;
- Few restrictions on size of work piece;
- Ideal for testing wrought materials and welds;
- Requires access to one surface of the test piece;
- Highly portable;
- Equipment is relatively inexpensive;
- Can be fully automated for scanning uniform shapes.

Disadvantages

- Rough or uneven surface must be ground smooth.
- Interpretation of results dependent on skill, knowledge, and experience of operator.
- No permanent record of the observations. (Methods have been recently developed to digitize the screen image which can then be computer enhanced and/or printed.)
- High noise levels are produced by coarse grain structures such as cast iron which reduce test efficiency.

References

- See References 8, 15-16

4.1.1.4 Eddy Current

Eddy current testing is a method based on the principles of electromagnetic induction. The component or part thereof to be tested is placed within or adjacent to a coil which is excited by an alternating current.

As the induced current fluctuates, an eddy current is produced which flows in a closed loop inside the test material. The flow of this eddy current is affected by the electrical properties of the part and the existence of defects distorts the electromagnetic field within the part.

When defect free material is being tested the eddy current flow remains uniform. In the presence of a crack or other defect, the eddy current flow is impeded and changes direction, which in turn alters the electromagnetic field. Eddy current instruments are designed to detect and monitor these changes.

Advantages

- Can be used for rapid inspection of planar shapes;
- Ideally suited for non-ferrous materials
- Contact of coil or probe with surface not necessary but a consistent separation must be maintained;
- Thin, uniform coatings do not have to be removed;
- Detects very small discontinuities;

PART 4 – ADDITIONAL INVESTIGATIONS

- The size of the defect can be estimated;
- No couplants or post cleaning needed;
- Good method for sorting materials, checking heat treatment, and detecting hardness variations.

Disadvantages

- Not suitable for complex shapes;
- Shallow penetration of parts, detects surface and subsurface defects only;
- Needs reference samples for comparison purposes;
- Material must be electrically conductive;
- Surfaces must be smooth and uniform;
- Skilled and experienced technicians required to interpret the indirect test results.

References

- See References 8, 17

4.1.1.5 Radiographic Testing

This method is based on the ability of ionizing radiation in the form of X-rays or Gamma Rays to penetrate solid materials to produce an image on film or a fluorescent screen (Figure 4.1.1.8

The radiation is mostly absorbed when passing through sound and thick metal while it will pass more readily through cracks, defects, and thinner material. Any differences in density due to inclusions or gas cavities or thickness variations in the part being examined cause differences in the absorption rates of the penetrating radiation. The resulting images on the film appear in various shades of gray, depending upon the amount of radiation reaching the film. Since cracks or defects absorb less of the available radiation they create a darker image than the sound material.

The radiograph shown in Figure 4.1.1.9 Radiograph of a Double Vee Groove Metal Arc Weld in Steel.Figure 4.1.1.9 illustrates a typical X-ray radiograph of a metal arc weld with slag inclusions.

PART 4 – ADDITIONAL INVESTIGATIONS

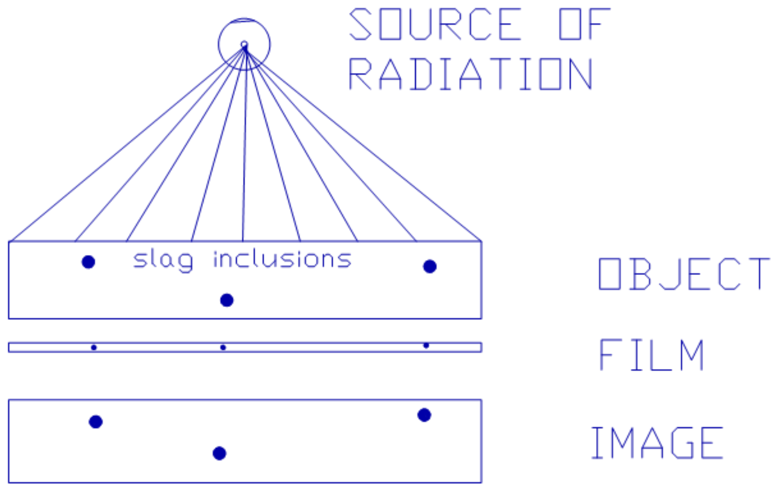

Figure 4.1.1.8 Schematic of Typical Radiographic Equipment

Under ideal field conditions, radiographic inspections can be used on most types of solid materials to reveal defects with depths or thicknesses greater than about 2% of the thickness of the material being examined. Cracks with depths of about 1.0mm or more should be detected under normal conditions when the plane of the crack is parallel to the direction of radiation.

This method is not well suited for testing in field conditions. It should, however, not be eliminated as a test method. The use of ultrasonic testing would be a suitable test method in place of radiographic testing.

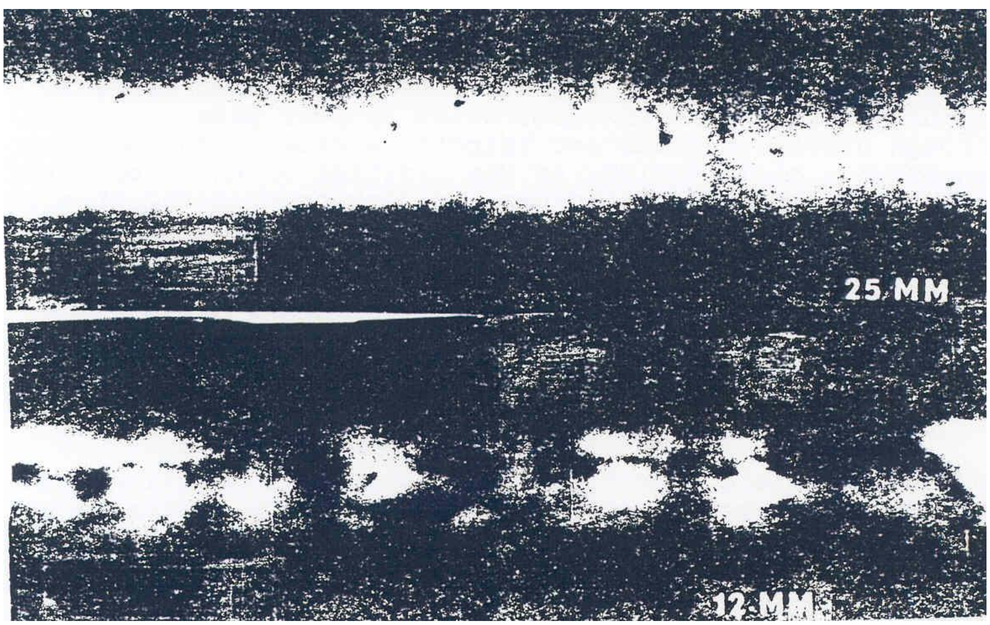

Figure 4.1.1.9 Radiograph of a Double Vee Groove Metal Arc Weld in Steel.

PART 4 – ADDITIONAL INVESTIGATIONS

The dark, contrasting spots are slag inclusions. The top portion of the image has acceptable slag inclusion, while the bottom image was considered severe.

Advantages

- Well suited for the detection of open cracks and internal defects particularly in welds (inclusions and porosity);
- Detects cracks oriented approximately parallel to the axis of the rays;
- Permanent record of defects can be produced on film;
- Image is geometrically correct relative to the size, shape and location of the defect and area examined;
- Method and equipment well known and accepted;
- Gamma ray equipment is more portable while the less portable x-ray equipment can produce better contrast and definition of defects.

Disadvantages

- Equipment is hazardous and subject to rigid government controls. GAMMA RADIATION CANNOT BE TURNED OFF! Radiation sources must be heavily shielded;
- Not able to determine the depth of a defect;
- Cannot detect defects oriented perpendicular to the axis of the rays. Varying degrees of detection capabilities for other orientations relative to the axis of the rays;
- Both faces of test area must be accessible;
- Equipment is bulky and may be difficult to use in areas with limited space or restricted access;
- Not well suited to the detection of fine, tight cracks.
- Testing is expensive, particularly in the field.

References

- See References 8, 18

4.1.1.6 Comparison of Non-Destructive Methods

All of the foregoing non-destructive testing techniques can be used to evaluate defects in bridge structures but some are more readily used than others. Which method or methods that are to be used will depend entirely upon the information to be derived.

Liquid penetrants are ideally suited in confirming the presence of a surface defect such as a crack which has been identified by some surface anomaly during a visual inspection. The technique will confirm a discontinuity on the surface of a component and show its size but with no indication of the depth. It is not particularly suited for a comprehensive testing program of welds and assemblies.

PART 4 – ADDITIONAL INVESTIGATIONS

Magnetic particle testing is a simple method for quickly evaluating extensive welds and surface areas. It too is most suited to detecting surface discontinuities although some sub-surface defects may also be detected if they are close to the surface. As with liquid penetrants, this method will delineate the aerial extent of a defect but will provide no indication of the depth.

Ultrasonic techniques provide a means to identify and measure both surface and subsurface discontinuities quickly and economically although specific procedures are required that are unique to the component under test. Defects within the material appear as anomalies on the screen and through interpretation by the testing technician, the size of the defects can be estimated.

Eddy current testing will provide accurate detection of surface and near surface defects but requires the surface to be quite smooth; any irregularities complicates the interpretation of the results. This method is ideally suited to shop inspection of large planar surfaces but as the geometry of the component under test becomes more complex the observations become more difficult to interpret. The success of this technique is highly dependent upon the experience and expertise of the testing technician.

Radiography is a major non-destructive testing method which is routinely applied to the examination of welds and assemblies during fabrication. It is ideally suited to the detection of voids, inclusions, porosity, open cracks etc., where both faces of the component are accessible. A photographic image of a defect is produced illustrating its extent but not its depth. The equipment is expensive and requires special precautions to protect against radiation hazards, as is generally not recommended for use in the field.

6.1 gives a relative comparison of each test method to assist the user in selecting a suitable method for a particular application.

Table 4.1.1 Comparison of Non-Destructive Methods

	Inspection Method				
G – Good F – Fair/Marginal P – Poor N – Not Suitable	Liquid Penetrant	Ultra-sonic	Magnetic Particle	Eddy Current	Radiography
<u>In-Service</u>					
Fatigue Cracks	G	G	G	G	P
Stress Corrosion	G	G	G	N	F
Corrosion Pits	F	G	N	N	G
Surface Cracks					
<u>General</u>					
Surface Cracks	F	P	G	G	N
Deep Surface Cracks	G	G	G	G	F
Internal Cracks	N	G	N	N	F
Internal Voids	N	F	N	N	G
<u>Welds</u>					
Slag Inclusions and Porosity	N	F	N	P	G
Surface Cracks	G	P	G	G	P

PART 4 – ADDITIONAL INVESTIGATIONS

Internal Cracks, Lack of Fusion and Penetration	N	G	P	N	G

4.1.2 References For NDT Of Structural Steel

1. American Society for Metals (ASM), Metals Handbooks, Non-destructive inspection and Quality Control. Website https://dl.asminternational.org/handbooks
2. American Welding Society (AWS) B1.10M/B1.10:2016 (Guide for the Non-destructive Examination of Welds)
3. American Welding Society (AWS) D1.1/D1.1M:2025 Structural Welding Code - Steel
4. ASTM E94/E94M-17 Standard guide for radiographic examination.
5. ASTM Volume 03.03: Non-destructive Testing (I): B594 — E2373 (2024 Edition)
6. ASTM E1032-19 Standard Practice for Radiographic Examination of Weldments Using Industrial X-Ray Film
7. CAN/CGSB-48.9712-2022 Non-destructive testing — Qualification and certification of NDT personnel
8. ASTM-E 165: Standard Practice for Liquid-Penetrant Inspection Method.
9. ASTM E1220-21 Standard Practice for Visible Penetrant Testing Using Solvent-Removable Process
10. ASTM E709-21 Standard Guide for Magnetic Particle Testing
11. ASTM E164-19 Standard Practice for Contact Ultrasonic Testing of Weldments

4.2 WOOD

4.2.1 Methods For Detection Of Defects In Wood Components

Wood components develop decay from many causes outlined in Part 2, Section 2.5.15 of this manual. There is potential for decay which results from the reaction between wood and iron giving rise to loose connections not adequately covered.

Methods for detecting deterioration in wood described herein are separated into two groups; namely, those which identify exterior or surface deterioration, and those which are used to assess deterioration in the body of the wood.

There is no single tool or method that can accurately determine the extent and severity of deterioration. Of the methods discussed, none can satisfactorily identify all defects, and each has its limitations. Usually, the information derived by using a number of simple tools (Figure 4.2.1.1

PART 4 – ADDITIONAL INVESTIGATIONS

Typical Tools Used for Testing Wood Condition - Figure 4.2.1.2

Figure 4.2.1.2 Typical Tools Used for Testing Wood Condition

) and methods together can provide a relatively accurate assessment of the extent of defects and deterioration in wood.

Figure 4.2.1.1 Typical Tools Used for Testing Wood Condition

PART 4 – ADDITIONAL INVESTIGATIONS

Figure 4.2.1.2 Typical Tools Used for Testing Wood Condition

4.2.2 Methods For Detection Of Surface Deterioration

4.2.2.1 Probing

Probing with a pointed tool, such as a knife, awl or screw driver, can locate decay near the surface of the wood. Decay is indicated by excessive softness and lack of resistance to penetration of the probe. Although the actual procedure is simple, experience is required to distinguish decay from water-softened wood which is otherwise sound. In addition, pressure treated wood may be sound on the surface but rotted beyond the treated layer.

Advantages

- Simple and quick procedure.

Disadvantages

- Some soft species, such as cedar, may be particularly difficult to assess using this method;
- Interpretation of results subject to experience of investigator;
- May not detect interior decay.

4.2.2.2 Pick Test

In this test, a pointed pick, screwdriver, or awl is driven a short distance into the wood, transverse to the grain, to pry out a sliver of wood from near the edge of a component. Sound wood has a fibrous structure and pries out as long splinters, while decayed wood breaks abruptly and crumbles into small pieces (Figure 4.2.2.1).

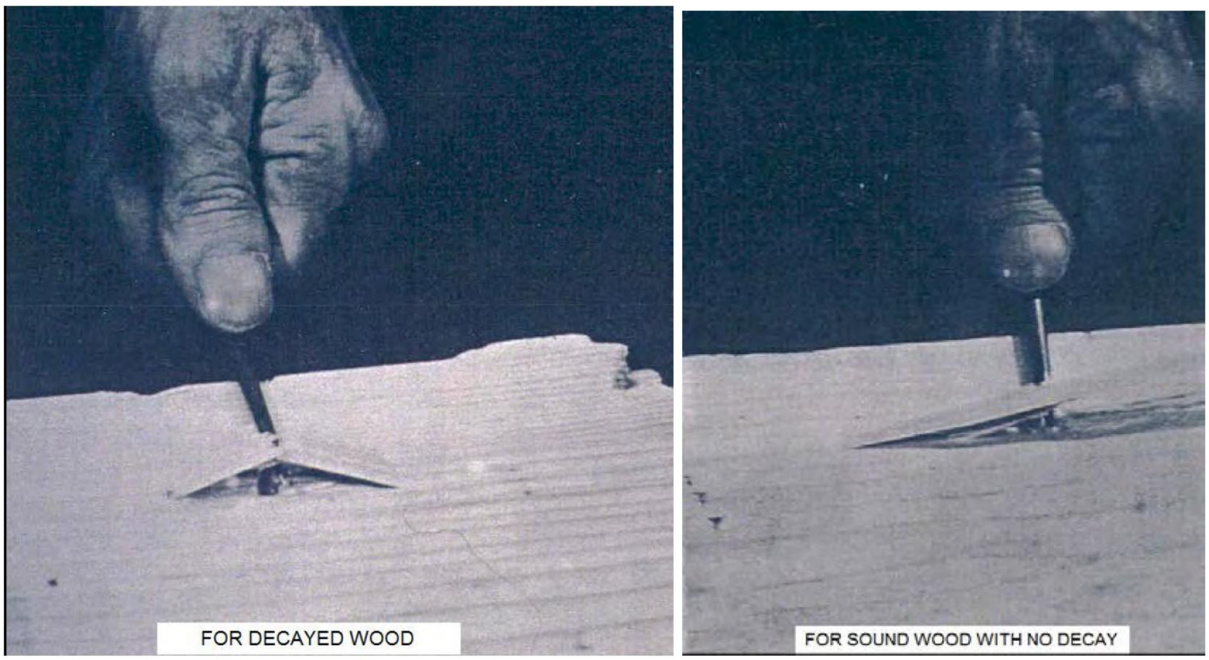

Figure 4.2.2.1 Pick Test

Advantages

- Simple and quick procedure

Disadvantages

- A large sliver of wood has to be removed for each test and leaves local damage to the treated surface. <u>This must be repaired;</u>
- May not detect internal decay.

4.2.2.3 Pilodyn

A pilodyn (Figure 4.2.2.2) is a spring-loaded pin device that drives a hardened steel pin into the wood. The depth of pin penetration is used as a measure of the degree of decay.

PART 4 – ADDITIONAL INVESTIGATIONS

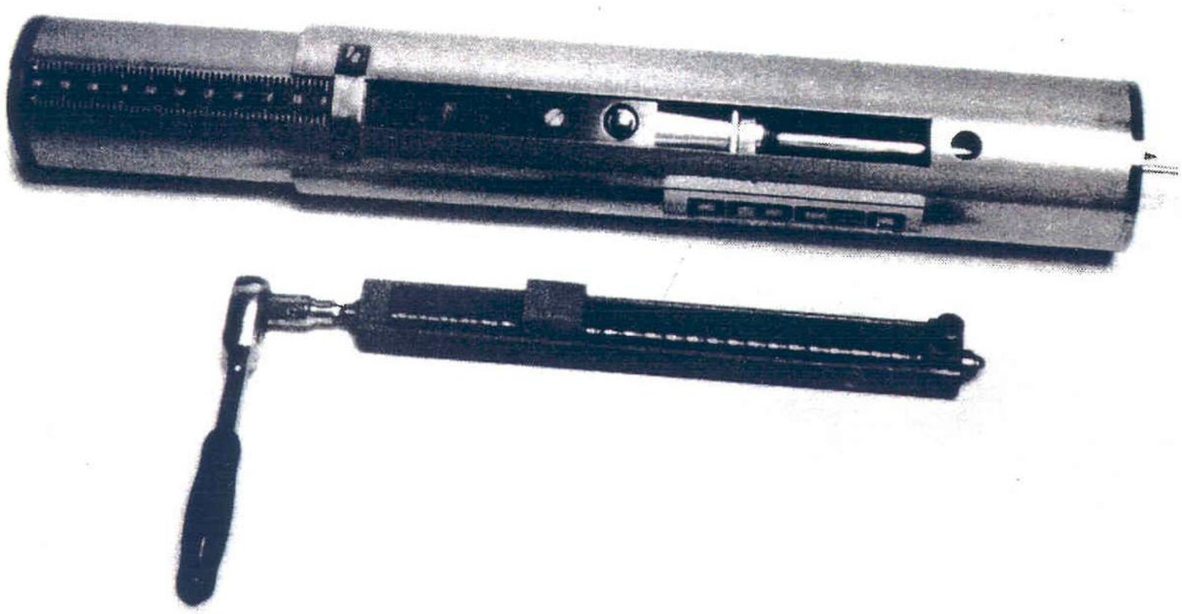

Figure 4.2.2.2 Typical Pilodyn used for assessing wood condition.

Advantages

- Can provide a relatively accurate calibrated/quantitative assessment of depth of decay;
- Simple and easy to use.

Disadvantages

- Equipment has to be calibrated, and results have to be corrected for moisture content and wood species;
- May not detect internal decay

4.2.3 Methods For Detection Of Interior Deterioration

4.2.3.1 General

Interior deterioration is more difficult to locate because there may be no visible evidence on the surface of the component. Several methods that can be useful in identifying probable decay are described. With each of these, the existence and extent of the problem should be confirmed and defined with core samples.

4.2.3.2 Sounding

Sounding is a commonly used method and involves striking the surface of the component with a hammer, or other similar object, and assessing the resulting tonal quality. A dull or hollow sound may indicate the presence of internal voids due to decay (Figure 4.2.3.1). However, other factors may be present which may make clear identification difficult.

PART 4 – ADDITIONAL INVESTIGATIONS

Figure 4.2.3.1 Simple use of a hammer to sound a wood timber. Decay is indicated by a hollow sound.

Advantages

- Quick and simple to apply;
- Can readily identify very severe deterioration.

Disadvantages

- Results are subject to interpretation by inspector;
- Cannot detect wood in incipient or intermediate stages of decay
- Cannot determine the extent of decay. Suspect decay must be verified by other methods such as boring and coring.

4.2.3.3 Moisture Meter

A moisture meter measures the electrical resistance of the wood between two metal pins which are driven into the surface (Figure 4.2.3.2). The resistance measured is then correlated to the moisture content in the wood. A centre probe between the pins indicates the depth of penetration of the pins. The pins are removable and available in various lengths for determining moisture contents to depths up to 75mm into the wood. The holes left by the pins can be repaired by treating with preservative.

A measure of the moisture in wood will provide an indication of conditions that are conducive for decay. Moisture contents in excess of about 30% indicate conditions suitable for decay. If the measurements are carried out after a severe or prolonged period of dry weather, then moisture levels of 20 to 25 percent may be cause for concern.

An alternative instrument to check for moisture is a shigometer. The shigometer uses a pulsed current to measure changes in electrical conductivity associated with wood decay. A small hole is drilled into the wood (Figure 4.2.3.3) and a probe is inserted into the hole (Figure 4.2.3.3 (b)). The probe measures zones or regions of decreased resistance. If the readings drop 50% to 75% to that of sound wood, the region is drilled and cored to determine the extent and nature of the decay.

Figure 4.2.3.2 Typical Resistance- Type Moisture Meter

PART 4 – ADDITIONAL INVESTIGATIONS

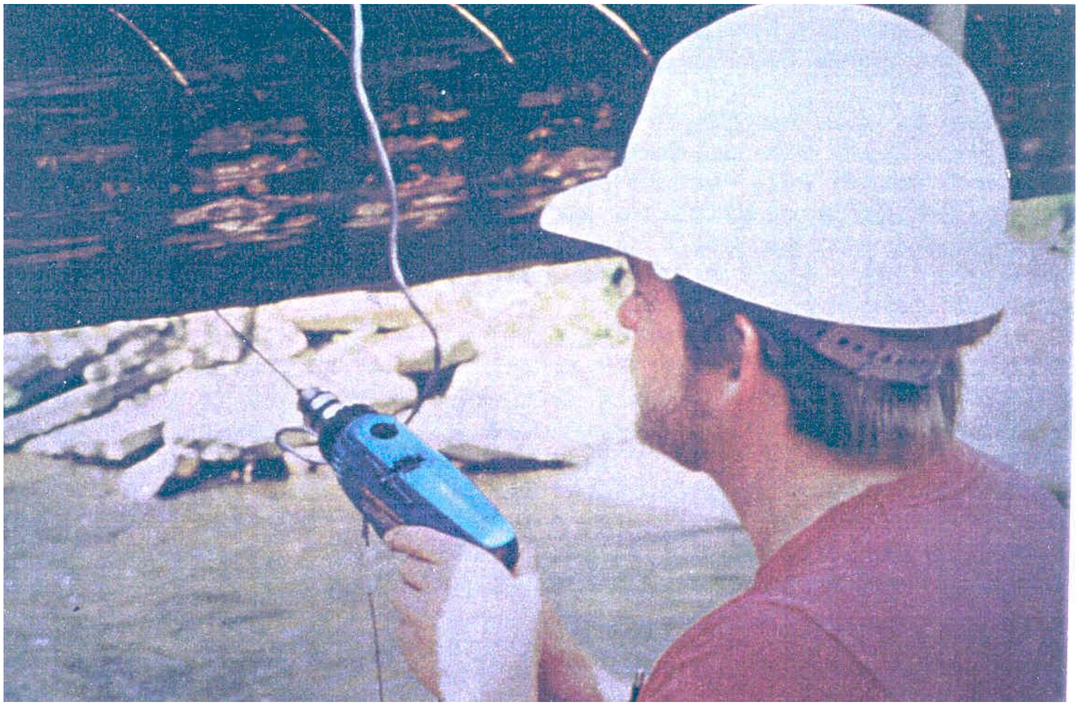

Figure 4.2.3.3 Drilling of the wood beam in preparation for the shigometer probe.

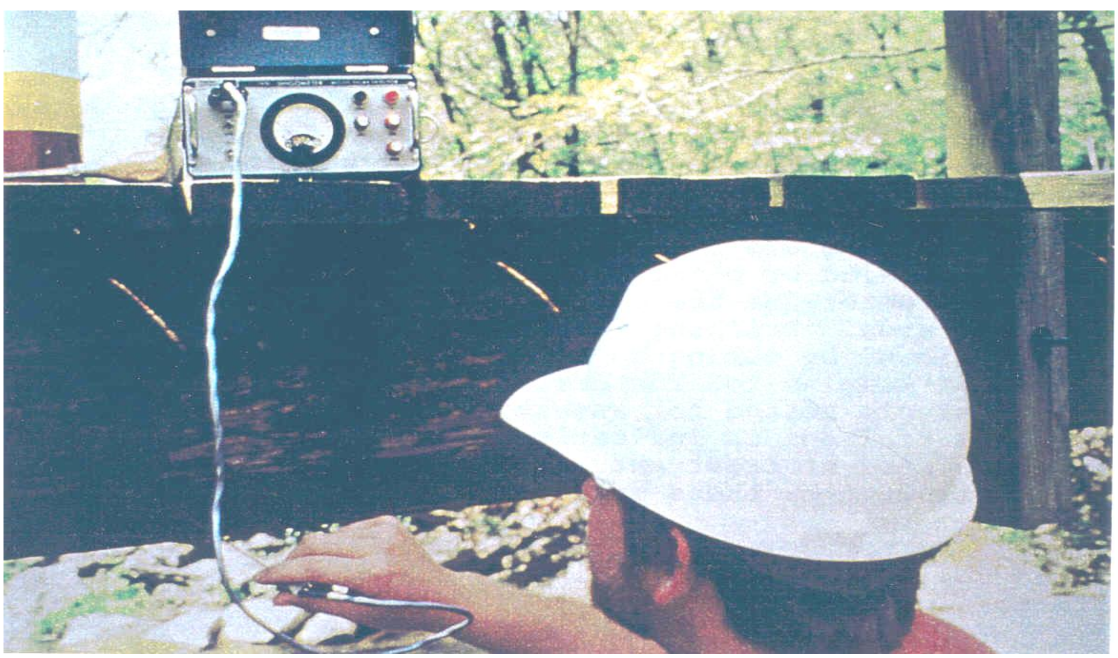

Figure 4.2.3.4 Application of the Shigometer Probe

Advantages

- Highly portable and easy to use;
- Can determine areas where decay is suspect or possible.

Disadvantages

- Does not directly detect decay;
- Must be calibrated and corrected for temperature conditions;
- Suspect areas must be evaluated by core sampling.
- Small holes left by the pins, potential areas for wood decay

4.2.3.4 Drilling and Coring

Drilling and coring are the most positive means to confirm the presence of internal voids and decay, and to determine the thickness of the remaining sound material.

In drilling, a hand drill with a 10mm to 20mm diameter bit is used to drill a hole into the wood. Zones or pockets of decay and deterioration are noted by ease of drilling and by examination of wood shavings. Although power drills may be faster, a hand drill is more suitable, giving the inspector better control and feel in detecting soft pockets.

Coring with an produces a length of solid core from the wood which can be directly examined for decay and tested. The equipment used for coring and extraction of a wood core is shown in Figure 4.2.3.5 to Figure 4.2.3.7.

Drilling and coring are generally used to confirm suspect areas of decay identified by other methods (sounding, moisture meter etc.), and to determine the extent or limits of decay, in terms of depth and area. Drilling is often used to establish evidence of decay followed by coring to define the limits of decay and extraction of samples for further laboratory analysis. Culturing provides a simple method for assessing potential risk of decay. The presence of fungi is indicative of wood in an early stage of decay and in need of treatment.

Drill bits and borers must be sharp. Dull tools will break, crush, and splinter the wood making interpretation of samples and results difficult.