Workshop on Welding Series

Module 2 : NDT

(Non-Destructive Testing)

(30 December 2013)

by Castco Testing Centre Ltd

Non-Destructive Testing (NDT)

Non-Destructive Testing (NDT)

- DT is one of the methods to determine the suitability of a given base metal or a weld to perform its intended service
- The major disadvantage of DT is the test object is destroyed in the process
- NDT has been developed to provide an indication of the acceptability of the test object without rendering it unusable for service.

Non-Destructive Testing (NDT)

Type of Test	Symbol
Acoustic Emission	AET
Eddy Current	ET
Leak	LT
Magnetic Particle	MT
Neutron Radiographic	NRT
Penetrant	PT
Radiographic	RT
Ultrasonic	UT
Visual	VT

Dye-Penetrant Testing (PT)

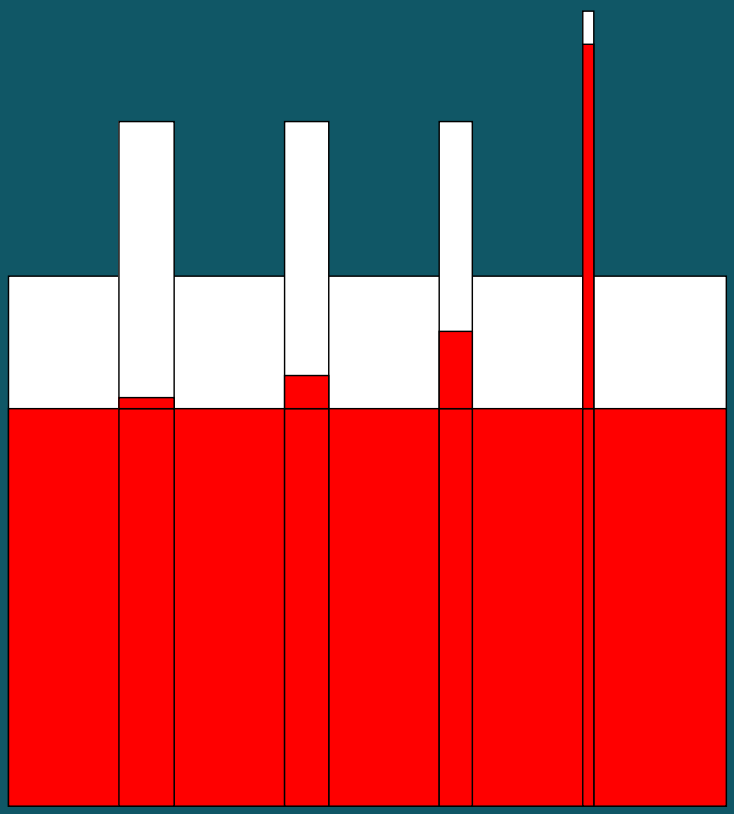
Dye Penetrant Testing

Introduction

- Sensitive method for locating surface discontinuities (cracks, porosities)
- Reveals surface discontinuities by the bleedout of a penetrating medium against a contrasting colored background
- Penetrant is remained on the surface for a prescribed time (dwell time) for allowing penetrate into any surface opening

Dye Penetrant Testing

- Subsequent removal of excess penetrant and application of a developer draws remaining penetrant from discontinuities
- The resultant indications are shown in high contrast and magnify the presence of the discontinuity so that it can be visually interpreted



Capillary Action

Dye Penetrant Testing

Type of Penetrant indications

- Visible dye
  - Usually red, produces a vivid red indication against a white developer background when viewed under white light
- Fluorescent penetrant
  - Produces a greenish and fluorescent indication when observed under ultraviolet (black) light

Dye Penetrant Testing

- Use of fluorescent penetrant can result in a more sensitive test (human eye can more readily perceive a fluorescent indication than a visible indication)

Dye Penetrant Testing

Operational Procedural Steps

1. Pre-cleaning the test surface
2. Application of penetrant
3. Cleaning of Penetrant
4. Application of Developer

Dye Penetrant Testing

1. Pre-cleaning the test surface

- The test object should be free of oil, dirt, rust, paint, etc.
- Prevent the block of surface openings of a discontinuity
- Care must be taken if mechanical cleaning technique is used, an aggressive mechanical cleaning operation on soft material might tend to mask the surface metal

Dye Penetrant Testing

2. Application of penetrant

- Dry the surface before application of penetrant
- Application of penetrant by dipping, brushing or spraying
- Suitable **dwell time** must be allowed for the penetrant drawing into tight crack by capillary action (normally from 5 min to 30 mins)

Dye Penetrant Testing

- The exact time depends on the manufacturer's recommendations, the temperature of the part and the size of the discontinuities
- Kept moisture during the dwell time

Dye Penetrant Testing

3. Cleaning of Penetrant

- Thoroughly and carefully cleaned of the excess penetrant
- Should not be so aggressive that it washes penetrant out of shallow discontinuities

Dye Penetrant Testing

4. Application of Developer

- Developer can be a dry powder which readily evaporates, leaving the powder on the surface
- Should be applied in a thin, uniform layer and preferable to apply in several very thin layers (allowing a couple of minutes between successive developer for avoiding excessive developer buildup)

Dye Penetrant Testing

Advantages

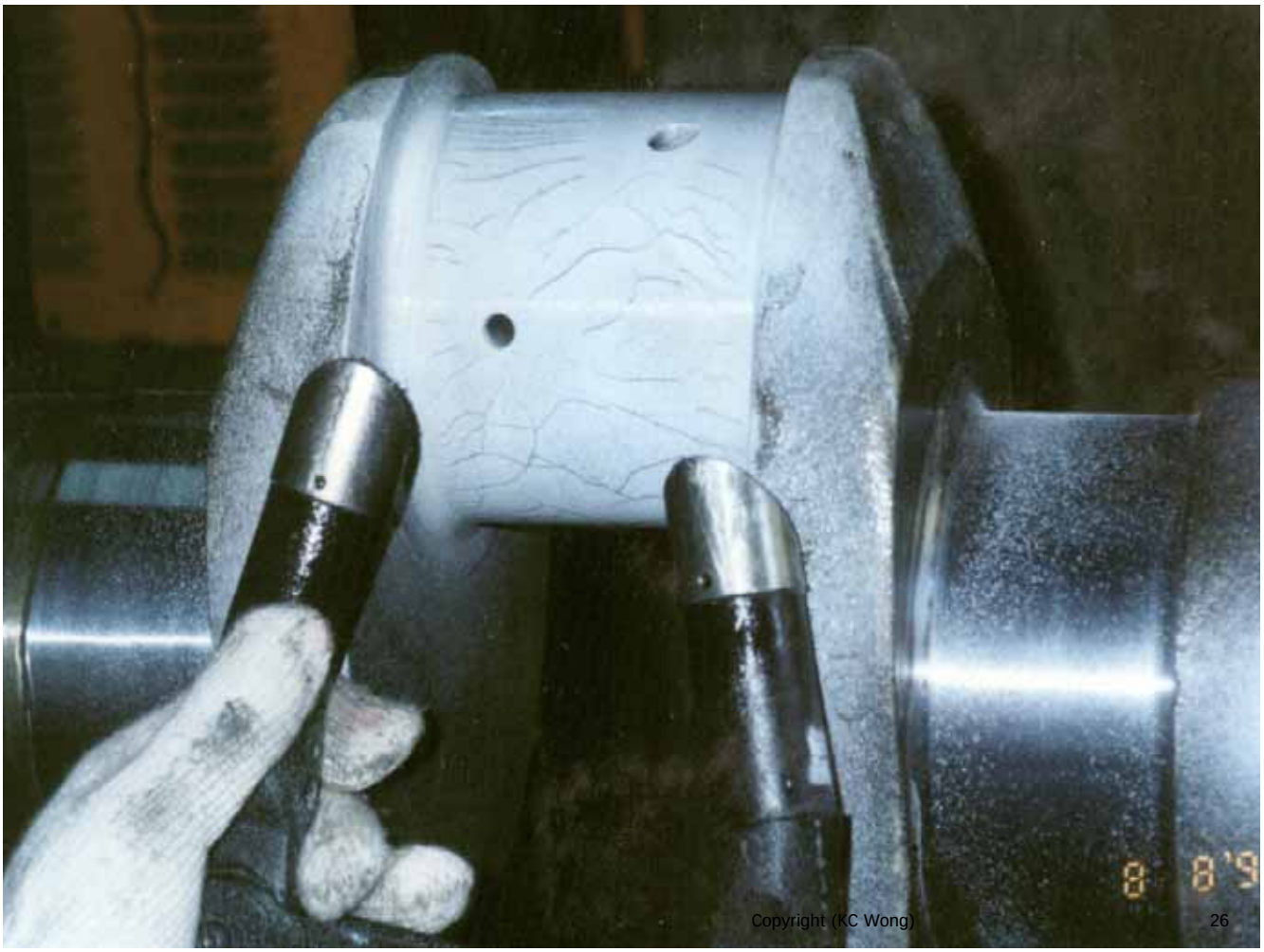
- Not limited to metallic test object
- Relatively inexpensive and reasonably rapid
- Simple, portable and little difficulty in learning
- Can be applied to nonmagnetic metals when other techniques are not applicable
- Well suited for evaluating weld or braze joints between dissimilar metals

Dye Penetrant Testing

Limitations

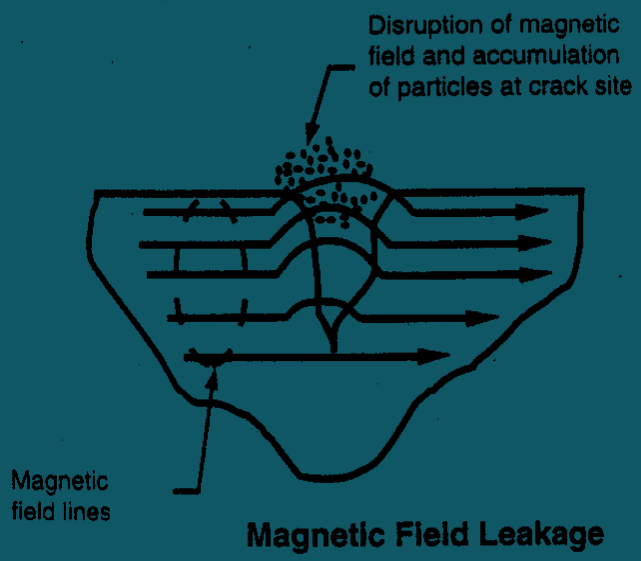
- Discontinuities must be cleaned and open to the surface
- Will not detect subsurface discontinuities
- Time-consuming test
- Deleterious effects on the welds and base metal (affect service life)
- Penetrants are difficult to remove completely from discontinuities
- Surface condition has a significant effect on their reliability

Magnetic Particle Testing (MT)



Magnetic Particle Testing

Primarily to discover surface or near surface discontinuities in ferromagnetic materials



Magnetic Field Leakage

Magnetic Particle Testing

Working principle

- Establishment of a magnetic field in the test piece with the aid of prods, yokes, or coils
- If the area is sprinkled with iron particles, those particles will be attracted and held in place at the discontinuities providing a visual indication
- Discontinuity is revealed by the build-up of iron powder particles

Magnetic Particle Testing

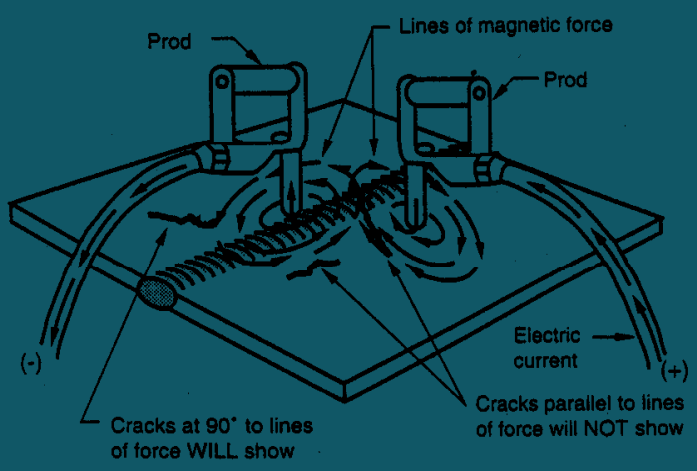
Magnetization

- Direct magnetization (Prod Method)
- In-direct magnetization (Yoke Method)

Magnetic Particle Testing

Direct magnetization (Prod Method)

Passing an electric current through the weld

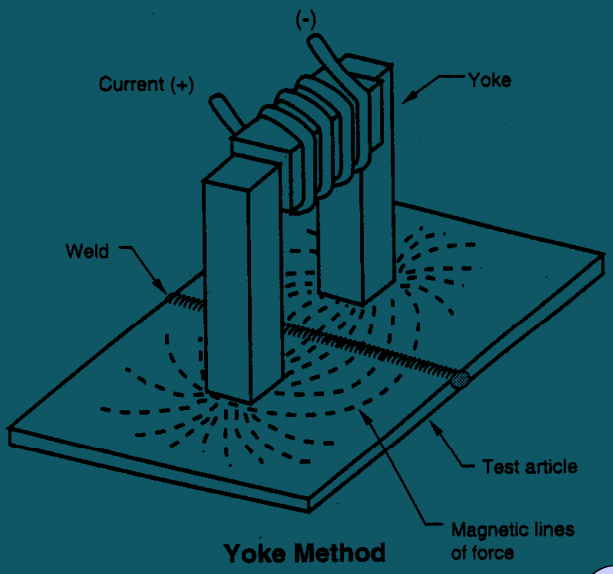


Prod Method

Magnetic Particle Testing

In-direct magnetization (Yoke Method)

By placing the test piece in a magnetic field



Yoke Method

Magnetic Particle Testing

Type of Magnetic Fields

- Longitudinal
- Circular

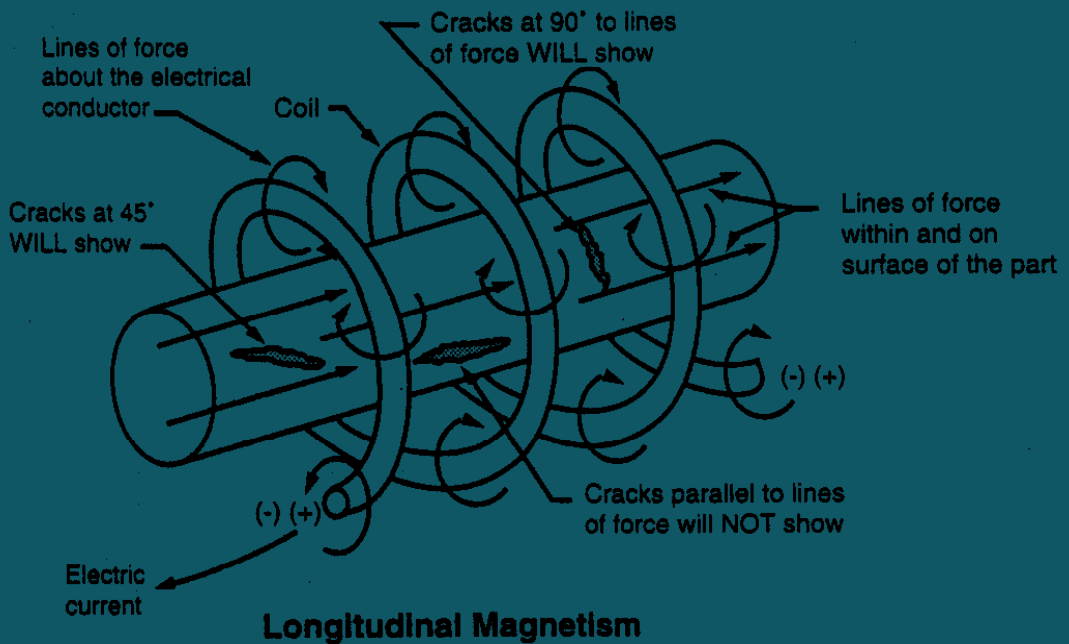
ONE WAY

Magnetic Particle Testing

Longitudinal

- If the magnetic field is oriented along the axis of the part, it is referred to as longitudinal magnetism
- Would also be referred to as a “Coil Shot”
- Those flaws lying perpendicular to the lines of force will be easily revealed. (45 degree to the magnetic field will also be shown)
- Will not be revealed if it lies parallel to the induced magnetic field

Longitudinal Magnetic Flied



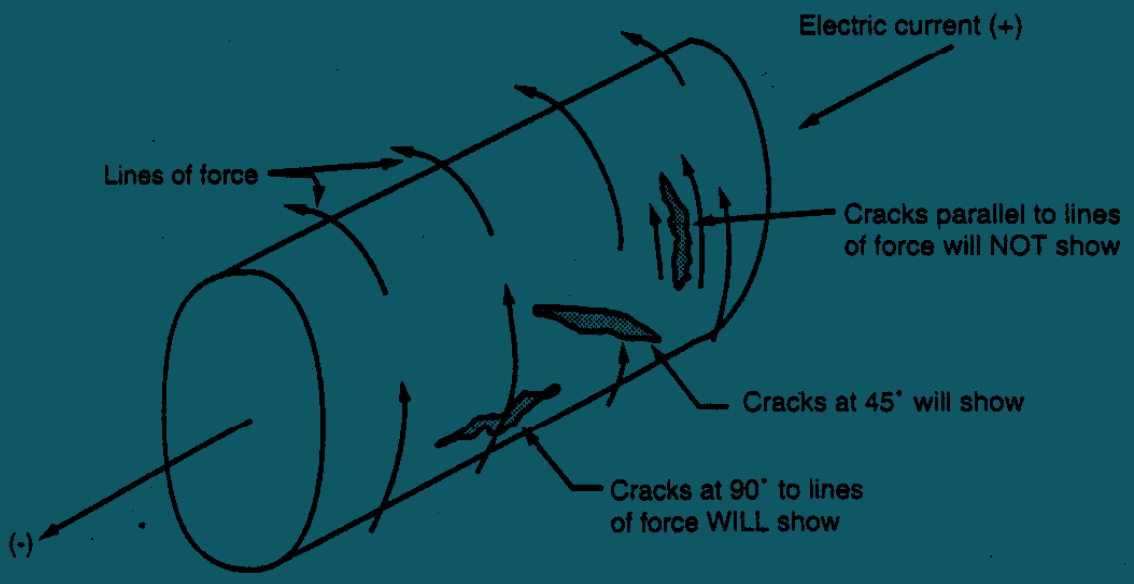
Longitudinal Magnetism

Magnetic Particle Testing

Circular

- When the direction of the magnetic field is perpendicular to the axis of the part, it is called circular magnetism
- Would also be called a “head shot”
- Those longitudinal flaws will be revealed but not transverse
- Flaws lying at 45 degree will also be shown

Circular Magnetic Flied



Circular Magnetism

Circular Magnetic Flied

- Circular magnetic field is generally considered to be somewhat more powerful, making circular magnetism more sensitive for a given amount of electric current
- To ensure complete evaluation of a part to locate flaws lying in all directions, it is necessary to apply the magnetic field in two directions 90 degree apart

Magnetic Particle Testing

Type of Current

- Alternative Current (AC)
- Direct Current (DC)
- Half-Wave Rectified Direct Current (HWDC)

Magnetic Particle Testing

Alterative Current (AC)

- Its characteristically changing magnetic field tends to increase the particles mobility on the surface
- Very low penetrating ability and only concentrate at the surface of the weld
- To improve test sensitivity when examining rough surfaces

Magnetic Particle Testing

Direct Current (DC)

- Tends to penetrate more deeply into the test piece
- Ability to detect discontinuities slightly below the surface
- Do not tend to more as readily on the surface as with AC

Magnetic Particle Testing

Half-Wave rectified Direct Current (HWDC)

- Combines the benefits of both types of magnetizing current
- Enhance particle mobility of AC ; and
- The deeper penetration of DC

Magnetic Particle Testing

Type of particles applied

- **Dye particles**
  - Are very small particles and are often dyed to provide a vivid color (red, white, etc.) contrast for greater visibility
  - Would also be called visible particles and are used under a strong visible light source

Magnetic Particle Testing

Type of particles applied

- Fluorescent particles
  - Coated with fluorescent dye to be viewed under ultraviolet light to achieve greater sensitivity

Magnetic Particle Testing

Type of particles applied

- Can also be classified as dry powder method or wet power method
- The wet fluorescent method has higher sensitivity

Magnetic Particle Testing

Capabilities of Magnetic Particle Testing

- Surface cracks of all kind of ferrous weld and base metal
- Laminations or other discontinuities on the prepared edge of the base metal
- Incomplete fusion if at or near the surface
- Subsurface cracks

Magnetic Particle Testing

Advantages

- Relatively simple
- Reveals discontinuities that are not open to the surface or filled with some substances (cracks filled with carbon, slag or other contaminants may not be detectable using PT)
- Faster and more economic than PT
- Less cleaning required prior to examining the part

Magnetic Particle Testing

Limitations

- Apply only to ferromagnetic materials
- Difficulties may arise where the magnetic characteristics of the deposited weld metal differ appreciable from those of the base metal
- Not expect to find deep-seated discontinuities
- Must be applied in at least two directions, approx. 90 deg. apart

Radiographic Testing

(RT)

Radiograhic Testing

Introductions

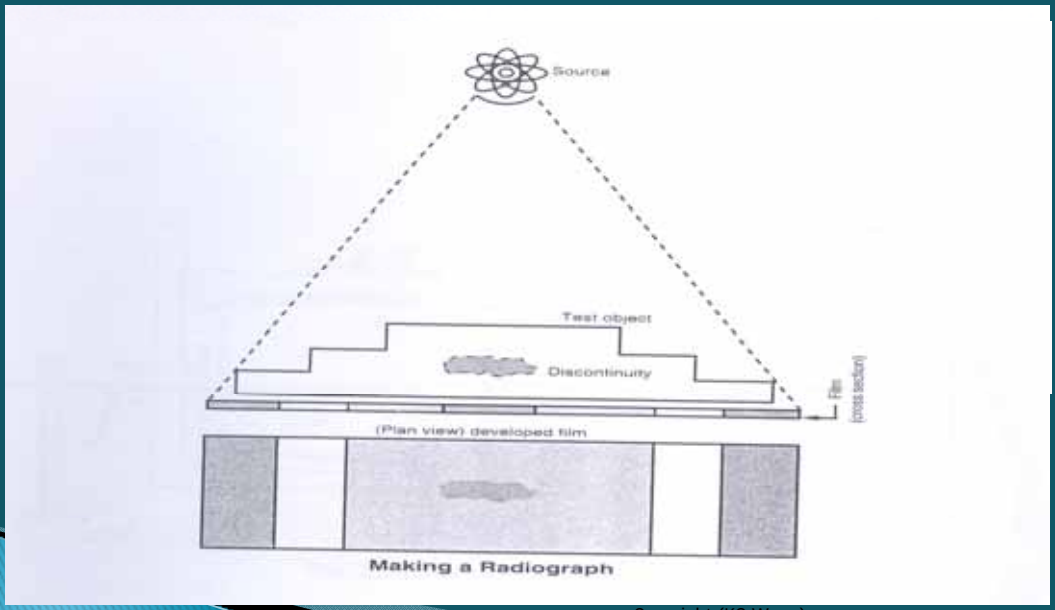
- suitable for all materials
- depends a great deal upon the weld joint location, joint configuration and material thickness
- but insufficient joint assess may prevent best use of the method. The welding inspector should keep this limitation in mind when asking for radiographic examinations.

Radiographic Testing

- Radiography uses X- or gamma radiation that penetrates through the testpiece
- Produces an image on a film or plate

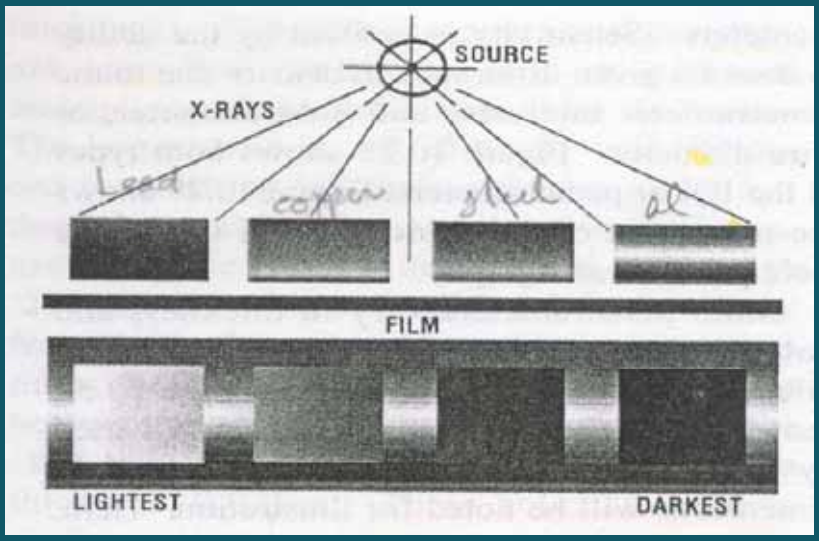
Radiographic Testing

- The density of the material in a discontinuity (air in the case of a crack, incomplete fusion of porosity) is less than that of the solid metal.



Radiographic Testing

- Different density materials attenuate the radiation in different amounts and consequently produce optical density differences on the film or plate.



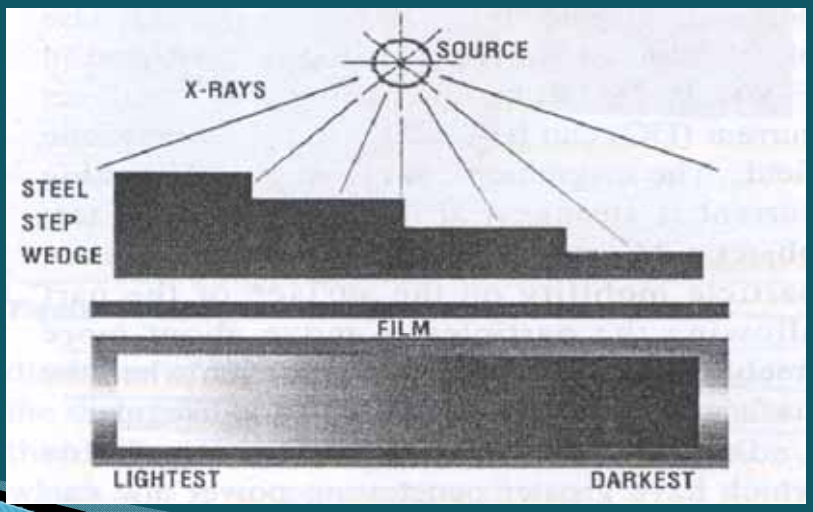
Radiographic Testing

- 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.)

ONE WAY

Radiographic Testing

- The thicker the material, the more effective is at stopping the radiation and thus producing a lighter film image



ONE WAY

Radiographic Testing

Selection of Radiation Sources

- 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.

Radiographic Testing

Selection of Radiation Sources

- Gamma Radiation
  - Are the result of the decay of radioactive materials
  - Are constantly emitting radiation and must be kept in a shielded storage container
  - Common used radioactive materials include
    - Iridium 192
    - Cesium 137
    - Cobalt 60
- X-rays
  - Are man-made and are produced when electrons strike the target

Radiographic Testing

Image Quality Indicators (IQI)

- Used to verify the resolution sensitivity of a given radiograph, a device refereed to as an image quality indicator(IQI), or penetrameter, is placed adjacent to the area of interest
- Sensitivity is verified by the ability to detect a given difference in density due to the penetrameter thickness and hole diameter
- **Shim** and **Wire** type are commonly used IQI

Radiograhic Testing

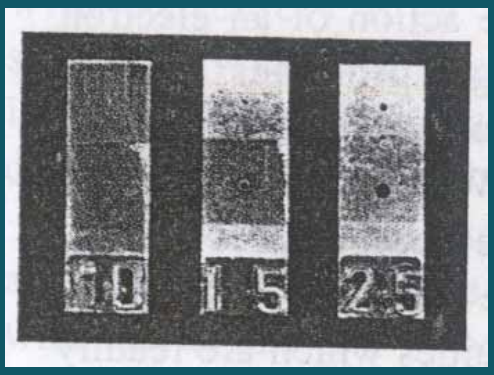
Wire Type

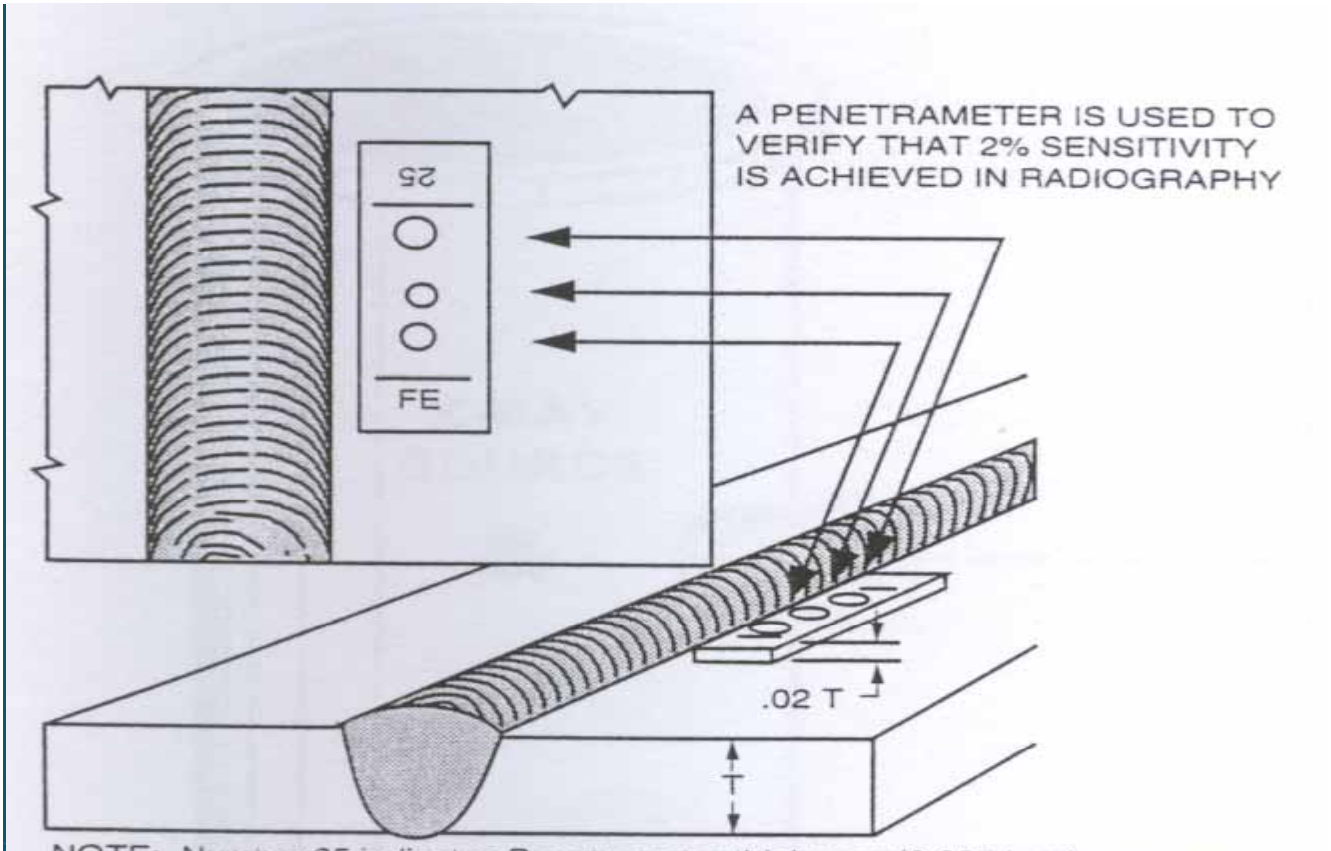
- Have specified diameters wire diameter

Radiographic Testing

Shim Type

- Have a specified thickness and included hole sizes
- Vary in thickness and hole diameters depending on the metal thickness being radiographed
- The holes are used to verify resolution sensitivity, which is usually specified to be 2% of the weld thickness





Typical Penetrameter

Radiograhic Testing

Equipment

- Either an X-ray machine requiring electrical input, or a radioactive isotope which produces gamma radiation
- Film and a light-tight film holder and lead letters are used to identify the test object
- Image Quality Indicators (IQI)
- Film processing equipment
  - Requires to develop the exposed film and a special film viewer with high intensity lighting is best for interpretation of the film

Radiographic Testing

Advantages

- Can detect subsurface discontinuities in all common engineering materials
- Serves as an excellent permanent record of the test

Radiographic Testing

Limitations

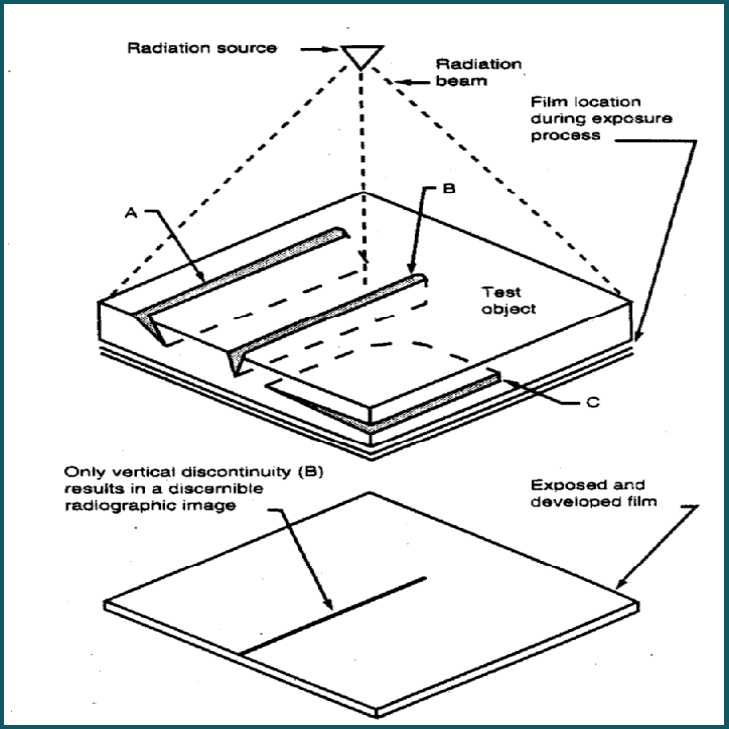
- The cost of radiography usually goes up as the joint becomes more complex, and the amount of information that can be obtained becomes more limited.
- Discontinuities must be more or less aligned with the radiation beam.

ONE WAY

Radiographic Testing

Limitations

- Discontinuities must be more or less aligned with the radiation beam.



Radiographic Testing

Limitations

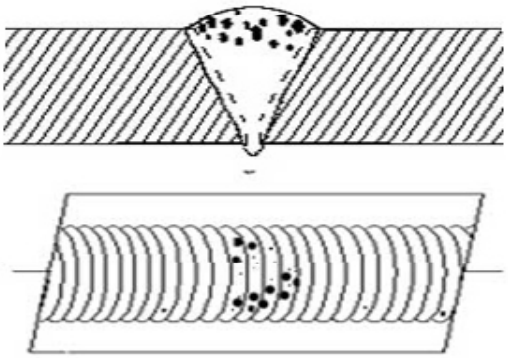
- Cracks, incomplete fusion and incomplete joint penetration must be aligned with the beam to be detected.
- Laminations and lamellar tearing are almost never detected with radiography due to their inherent orientation with respect to the radiation.

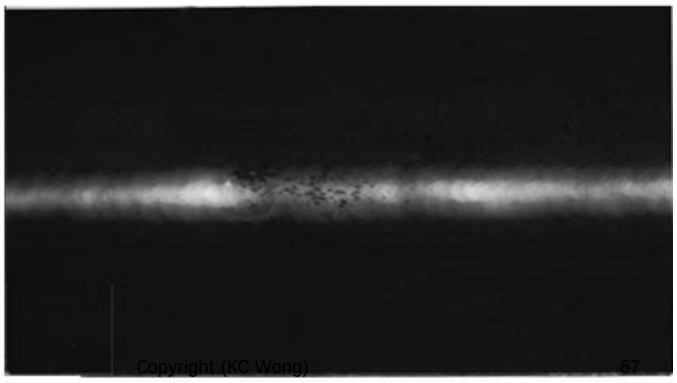
Radiograhic Testing

- The high cost of radiation sources and related equipment and facilities
- Associated with negative aspect of radiation hazard induce disease, permanent injury or death.

Radiographic Testing

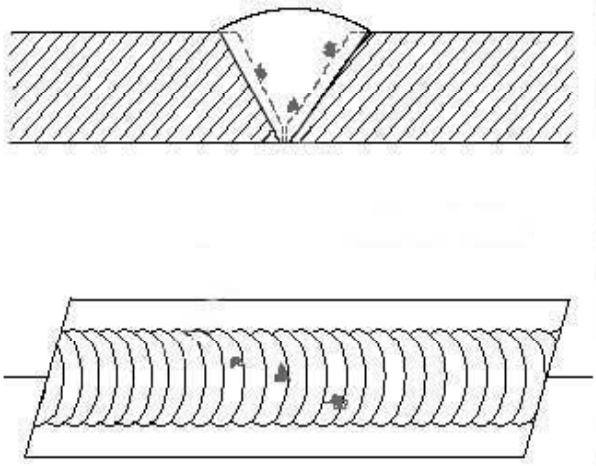
Cluster porosity is caused when flux coated electrodes are contaminated with moisture. The moisture turns into gases when heated and becomes trapped in the weld during the welding process. Cluster porosity appear just like regular porosity in the radiograph but the indications will be grouped close together.

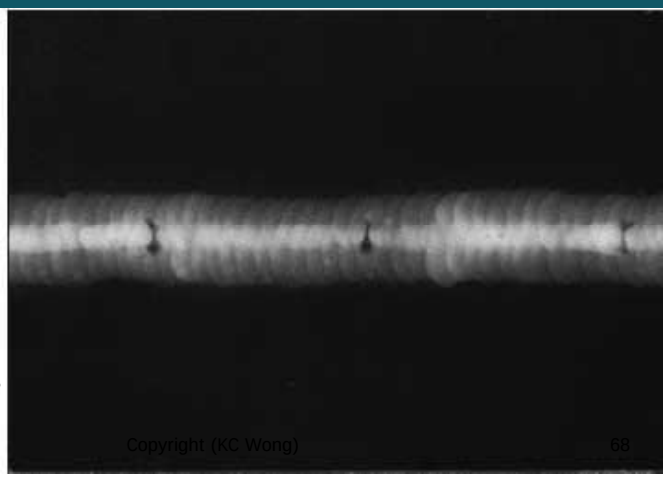




Radiographic Testing

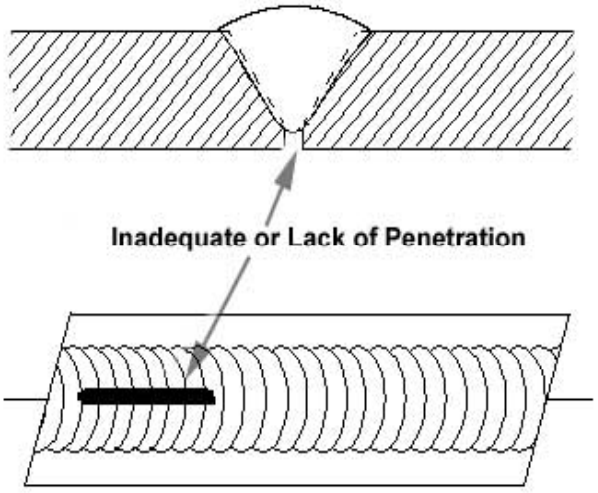
Slag inclusions are nonmetallic solid material entrapped in weld metal or between weld and base metal. In a radiograph, dark, jagged asymmetrical shapes within the weld or along the weld joint areas are indicative of slag inclusions.

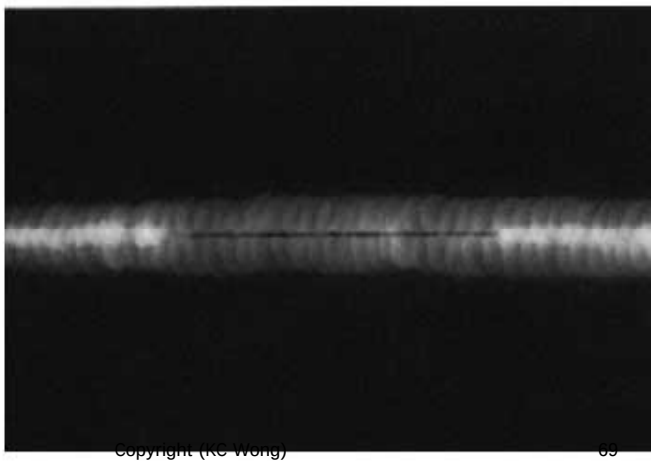




Radiographic Testing

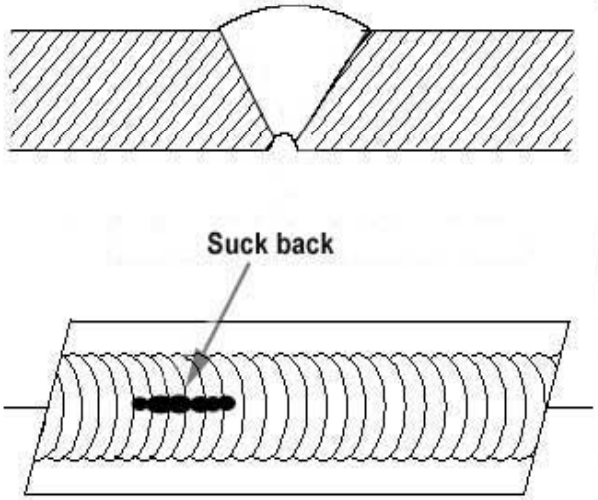
Incomplete Joint Penetration appears on a radiograph is a dark area with well-defined, straight edges that follows the land or root face down the center of the weldment.

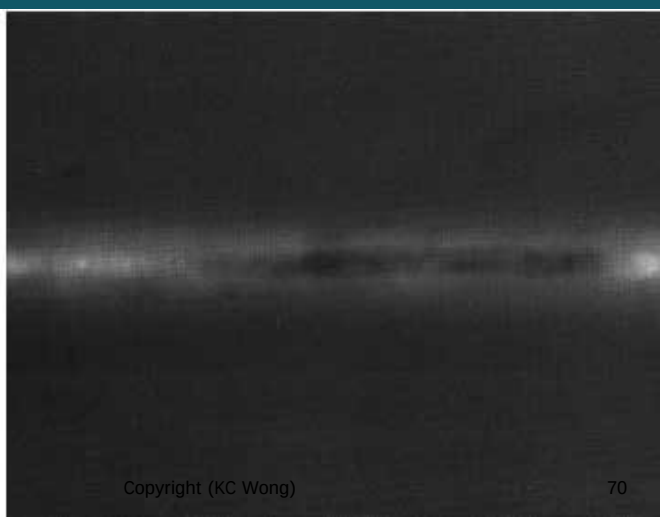




Radiographic Testing

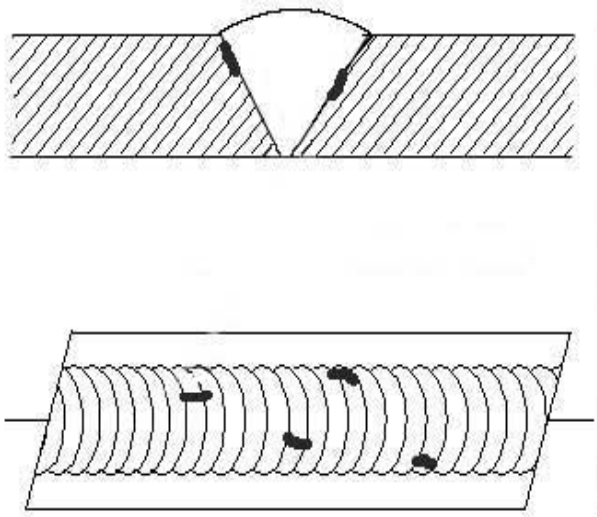
Root concavity or suck back looks similar to lack of penetration but the line has irregular edges and it is often quite wide in the center of the weld image.

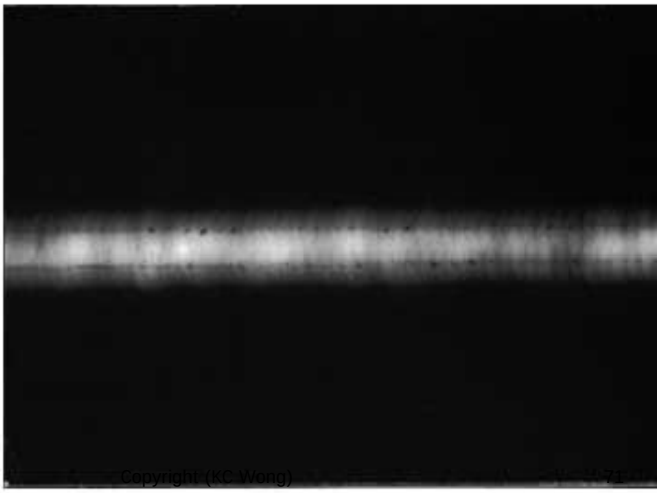




Radiographic Testing

Incomplete fusion appears on radiograph: usually appears as a dark line or lines oriented in the direction of the weld seam along the weld preparation or joining area.





Ultrasonic Testing

(UT)

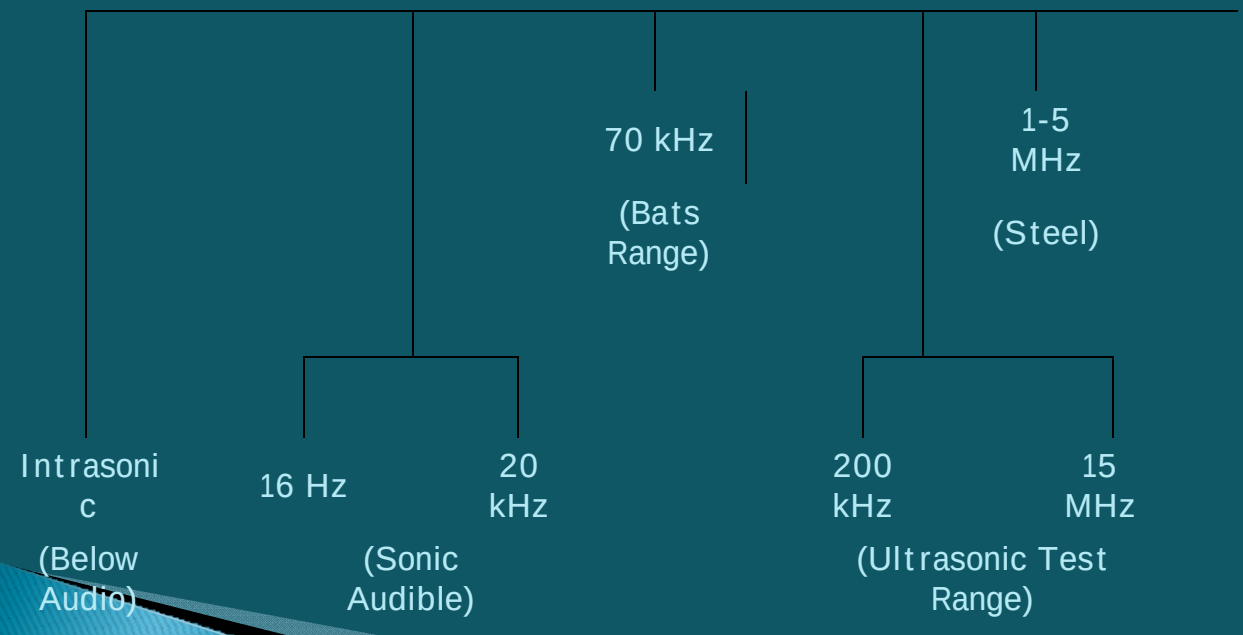
Ultrasonic Testing

Introductions

- 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.

Ultrasonic Testing

Acoustics



Ultrasonic Testing

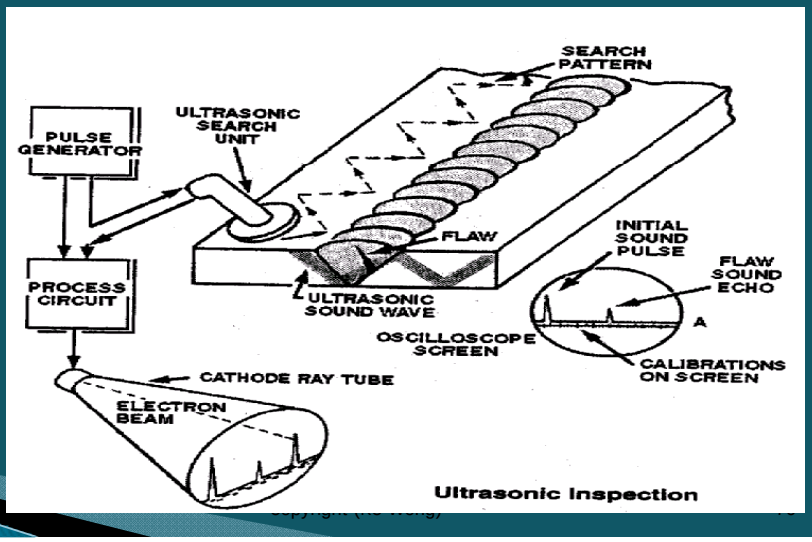
Velocity of sound in common materials m/sec

Material	Compressional	Shear
Aluminum	6320	3080
Steel	5920	3250
Copper	4700	2260
Brass	3830	2050

Ultrasonic Testing

Introductions

- 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.



Ultrasonic Testing

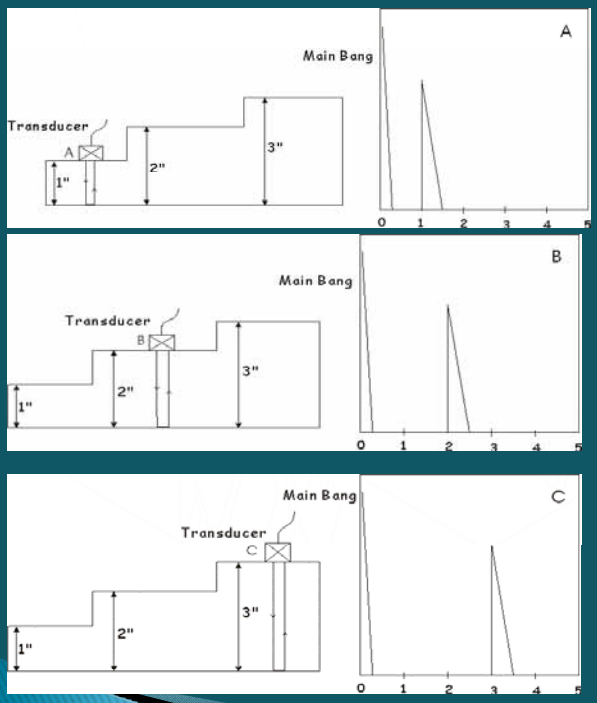
Introductions

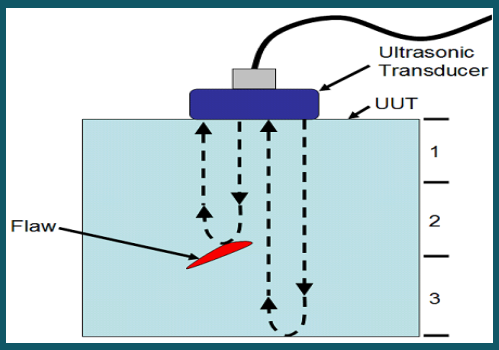
- The reflected sound is received as an echo, which together with the original pulse, is displayed on the screen of a cathode ray tube (CRT).
- The transducer accomplishes this energy conversion due to a phenomenon referred to as the "**Piezoelectric**" effect

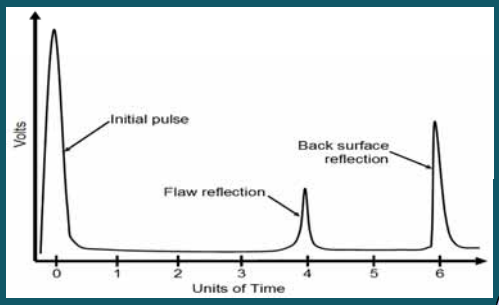
Ultrasonic Testing

- Before testing is begun, the instrument is **calibrated** against a reference block, such as the IIW (International Institute of Welding) calibration block.
- When the sound beam intercepts the plane of discontinuity at or near 90°, a maximum reflected signal might return to the transducer.
- In scanning welds, this is achieved by beams angled into the work through water, oil or similar couplant material.

Calibration Sequence for Longitudinal Beam Transducer







Ultrasonic Testing

Type of ultrasonic transducers

- Straight beam transducer or Longitudinal waves
  - Used to determine material thickness or the depth of a discontinuity below the material surface
- Angle beam transducer or Shear wave
  - Used extensively for weld evaluation
    - Send the sound into the part at an angle
    - Without the need for removal of the rough weld reinforcement

Ultrasonic Testing

Equipment used

- An electronic instrument with rather a CRT or digital display
- Transducers
- Couplant
- Calibration standard block

Ultrasonic Testing

Electronic Instrument

- An electronic instrument with rather a CRT or digital display
  - CRT – can determine the location, size and type of many discontinuities
  - Digital displays – usually limited to dimensional measurements such as metal thickness
- Transducers
  - Available in a wide variety of sizes and styles

Ultrasonic Testing

Couplants

- Oil, grease, water ,etc.

Calibration standard block

- For flaw detection, the calibration standards should meet the above requirements plus contain a machine “Flaw”
- For angle beam testing used in weld testing , the calibration standard block is the IIW Block

Ultrasonic Testing

Advantages

- 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 **(volumetric test)**
- The method is generally more sensitive for the discovery of planar type discontinuities than is radiography
- Laminations and lamellar tearing can be readily detected using ultrasonic testing.

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.

Ultrasonic Testing

Limitations

- Personnel must be qualified and require more training and experience
- 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.

THE END