
بسم الله الرحمن الرحيم

Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech

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Non-destructive testing (NDT)

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Outline

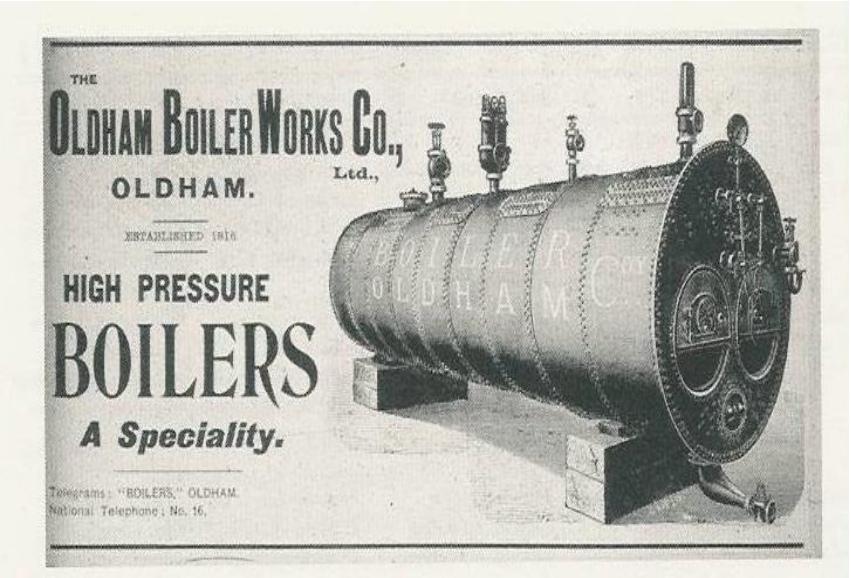
- NDT usages
- Penetrant test
- Magnetic Particles
- Eddy current
- Ultra-sonic
- X-Ray
- Selected Applications

History of NDE

- **Early events leading to NDE**

March, 1854 in Hartford, Conn. at the Fales and Gray Car Works

- People had returned from lunch and ~ 2:00 p.m. a boiler exploded destroying a good portion of the building. 21 people were killed and 50 seriously injured.
- Large safety factors, new materials, and reputable company did not prevent explosion due to too much steam pressure.
- A jury of peers suggested:
  - workman certification
  - safety inspections
  - limit location
  - provide minimum safety regulations



History of NDE

- **Inspection Laws**

  - 1857 – 12 men in Connecticut formed the Polytechnic Club met periodically to study problems related to boiler failures.

  - 1864 - Connecticut passed first boiler inspection law that provided guidelines for inspection and removed boilers that did not pass inspection.

Why use NDT?

- Components are not destroyed
- Can test for internal flaws
- Useful for valuable components
- Can test components that are in use

Methods of NDT

Visual

Thermography

Microwave

Magnetic Particle

Tap Testing

X-ray

Acoustic Microscopy

Acoustic Emission

Magnetic Measurements

Liquid Penetrant

Ultrasonic

Replication

Laser Interferometry

Eddy Current

Flux Leakage

What are Some Uses of NDE Methods?

- Flaw Detection and Evaluation
- Leak Detection
- Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Estimation of Mechanical and Physical Properties
- Stress (Strain) and Dynamic Response Measurements
- Material Sorting and Chemical Composition Determination

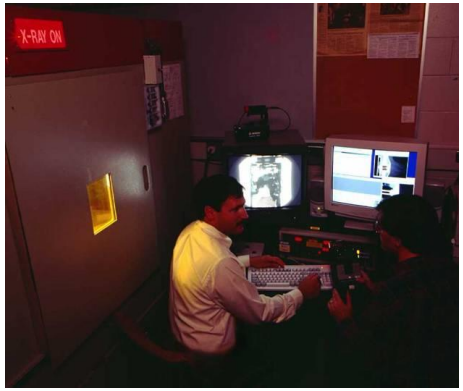
When are NDE Methods Used?

There are NDE application at almost any stage in the production or life cycle of a component.

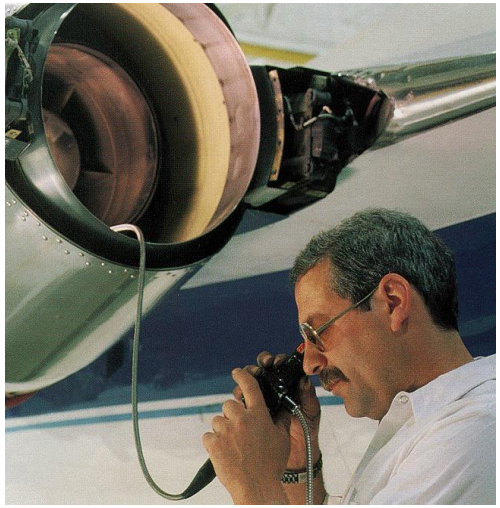
- To assist in product development
- To screen or sort incoming materials
- To monitor, improve or control manufacturing processes
- To verify proper processing such as heat treating
- To verify proper assembly
- To inspect for in-service damage

Six Most Common NDT Methods

- Visual
- Liquid Penetrant
- Magnetic
- Ultrasonic
- Eddy Current
- X-ray



Visual Inspection



Most basic and common inspection method.

Tools include fiberscopes, borescopes, magnifying glasses and mirrors.

Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.

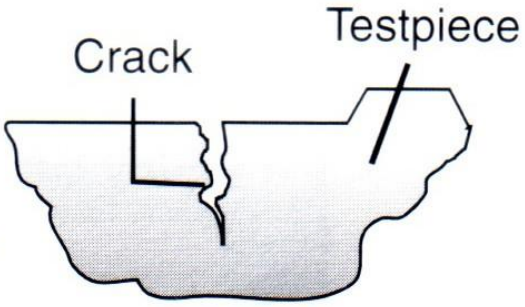
Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.

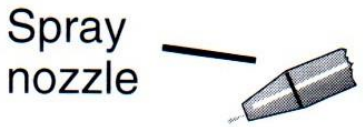
Liquid Penetrant testing

- Used for surface flaws.
- The *oil and chalk* test is a traditional version of this type of testing. Coloured dyes are now used.

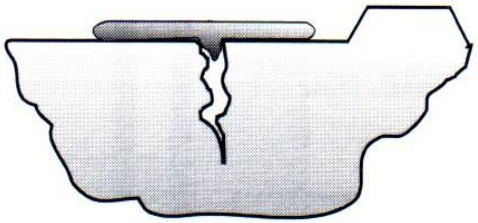
Penetrant testing for flaws

This method is useful for finding surface cracks

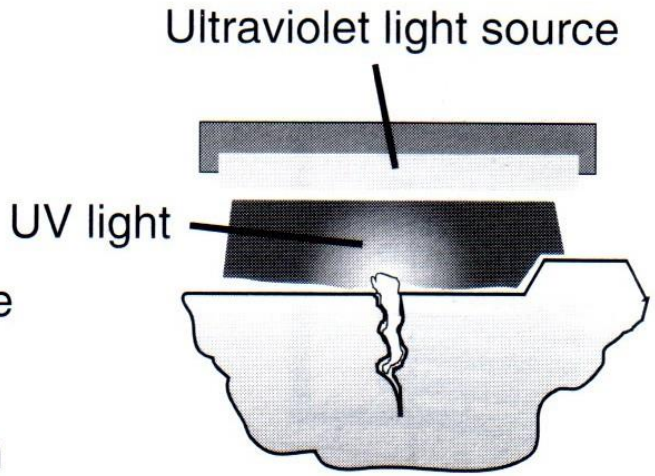




Fluorescent penetrant is applied by spraying and it soaks into any surface flaws

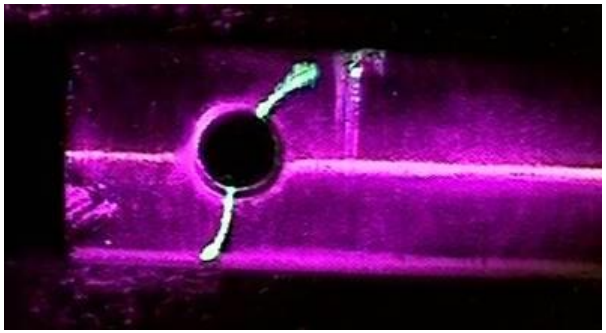


Under UV light the flaw *fluoresces* along the crack and is easily seen



Liquid Penetrant Inspection

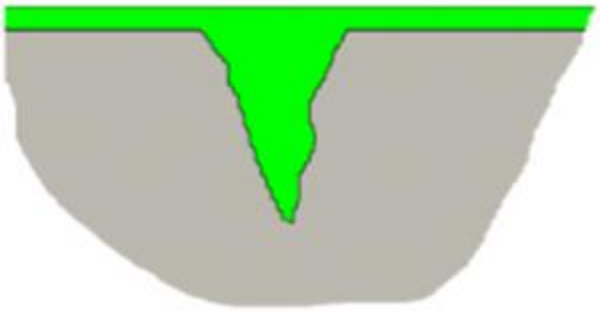
- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.
- Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.



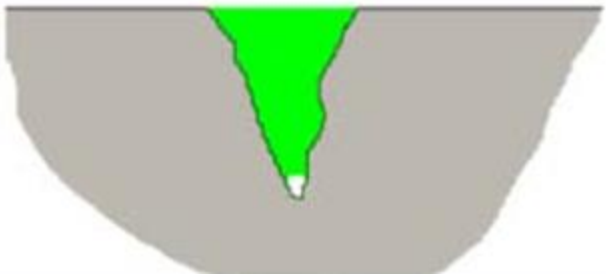
Basic Process of PT

1) Clean & Dry Component

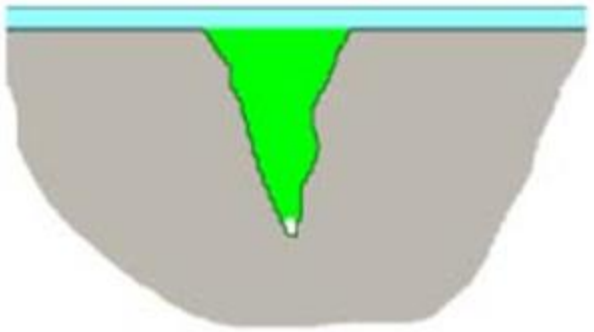
2) Apply Penetrant



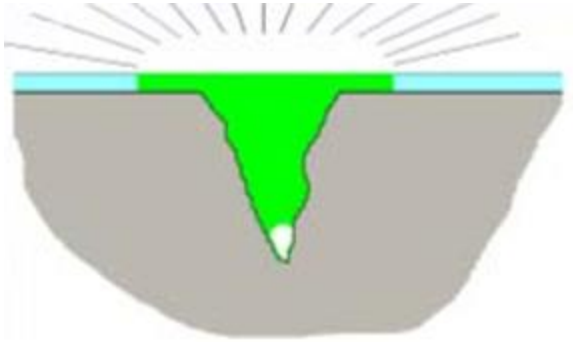
3) Remove Excess



4) Apply Developer



5) Visual Inspection



Typical Inspection Parts

Almost any material that has a relatively smooth, non-porous surface on which discontinuities or defects are suspected.

Difficult to Inspect

- Components with rough surfaces, such as sand castings, that trap and hold penetrant.
- Porous ceramics
- Wood and other fibrous materials.
- Plastic parts that absorb or react with the penetrant materials.
- Components with coatings that prevent penetrants from entering defects.

Pre-cleaning – Step 1

- Parts must be free of dirt, rust, scale, oil, grease, etc. to perform a reliable inspection.
- The cleaning process must remove contaminants from the surfaces of the part and defects, and must not plug any of the defects.

Pre-cleaning is the most important step!!!

Penetrant Application – Step 2

Many methods of application are possible such as:

- Brushing
- Spraying
- Dipping/ Immersing
- Flow-on
- And more

Dwell Time

- The penetrant solution must be allowed to “dwell” on the surface of the part to allow the penetrant time to fill any defects present.
- The dwell time vary according to penetrant type, temperature, material type and surface finish.

Excess Penetrant Removal – Step 3

The removal technique depends upon the type of penetrant used, as stated earlier…

- Solvent Removable
- Water Washable

Excess Penetrant Removal – Step 3 (cont.)

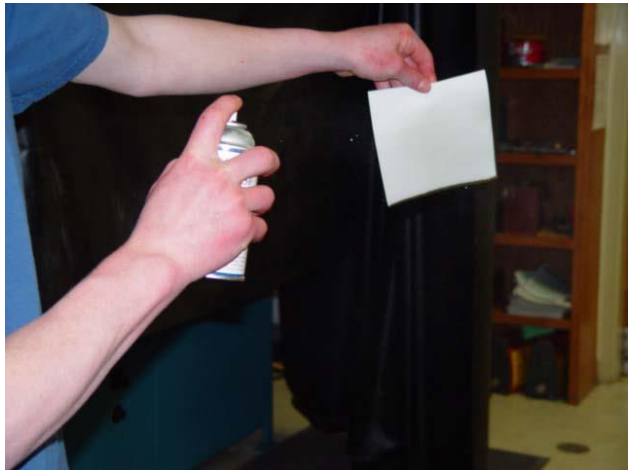
Water Washable

- A coarse water spray is used to remove the excess penetrant.
- The procedure used as a guideline for the inspection will specify water temperature (typically 50-100°F) and pressure (typically not more than 40 psi), etc.

Excess Penetrant Removal – Step 3 (cont.)

Solvent Removable

- The part is wiped with a clean dry cloth to remove the bulk of the excess penetrant.
- Then, a cloth lightly dampened with solvent is used to remove any remaining penetrant on the surface.



Excess Penetrant Removal – Step 3 (cont.)

Solvent Removable (cont.)

Any time a solvent is
used in the penetrant inspection process, a
suitable flash time is
required to allow excess solvent to
evaporate.

Developer Application – Step 4

The method of developer application is dependent on the type of developer used. The primary methods for the following main developer types will be covered in the following slides.

- Dry
- Wet
- Nonaqueous Wet

Developer Application – Step 4 (cont.)

Dry Powder Developer

- Prior to applying a dry powder developer, the component must be thoroughly dried. Drying is usually accomplished in a hot air circulating oven.
- The developer is then applied by immersing the part in the powder or by dusting of the part with the powder.
- The part can also be placed in a developer dust cloud chamber.

Developer Application – Step 4 (cont.)

Wet Developer (water- suspended and water- soluble)

- Wet developers are applied by immersing or spraying the part while it is still wet from the penetrant removal process.
- The part is completely coated and the excess liquid allowed to drain to prevent pooling
- The part is then dried in a hot air circulating oven.

Developer Application – Step 4 (cont.)

Nonaqueous Developer (AKA Solvent-Suspended)

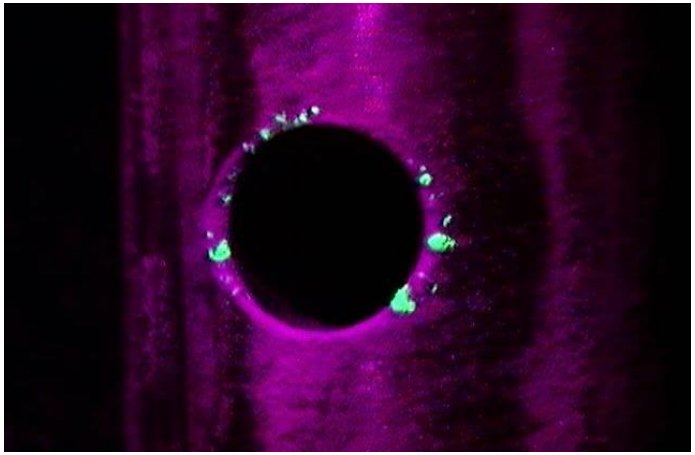
- Nonaqueous developer is applied by a aerosol spray to a thoroughly dried and cooled part.
- A thin even coating should be applied. The coating should be white but still slightly transparent when performing a visible dye penetrant inspection, and even thinner when performing a fluorescent penetrant inspection.

Inspection/Evaluation – Step 5

In this step the inspector evaluates the penetrant indications against specified accept/reject criteria and attempts to determine the origin of the indication.

The indications are judged to be either relevant, non-relevant or false.

Non-relevant weld geometry indications



Relevant crack indications from an abusive drilling process

Inspection/Evaluation – Step 5

A very important step of evaluation is to document findings on an inspection report form or other record keeping form.

This may be supported with drawings or photos of indications, etc.

Post Clean – Step 6

The final step in the penetrant inspection process is to thoroughly clean the part that has been tested to remove all penetrant processing materials.

The residual materials could possibly affect the performance of the part or affect its visual appeal.

Penetrant Inspection Systems

Penetrant systems can be highly portable or stationary.

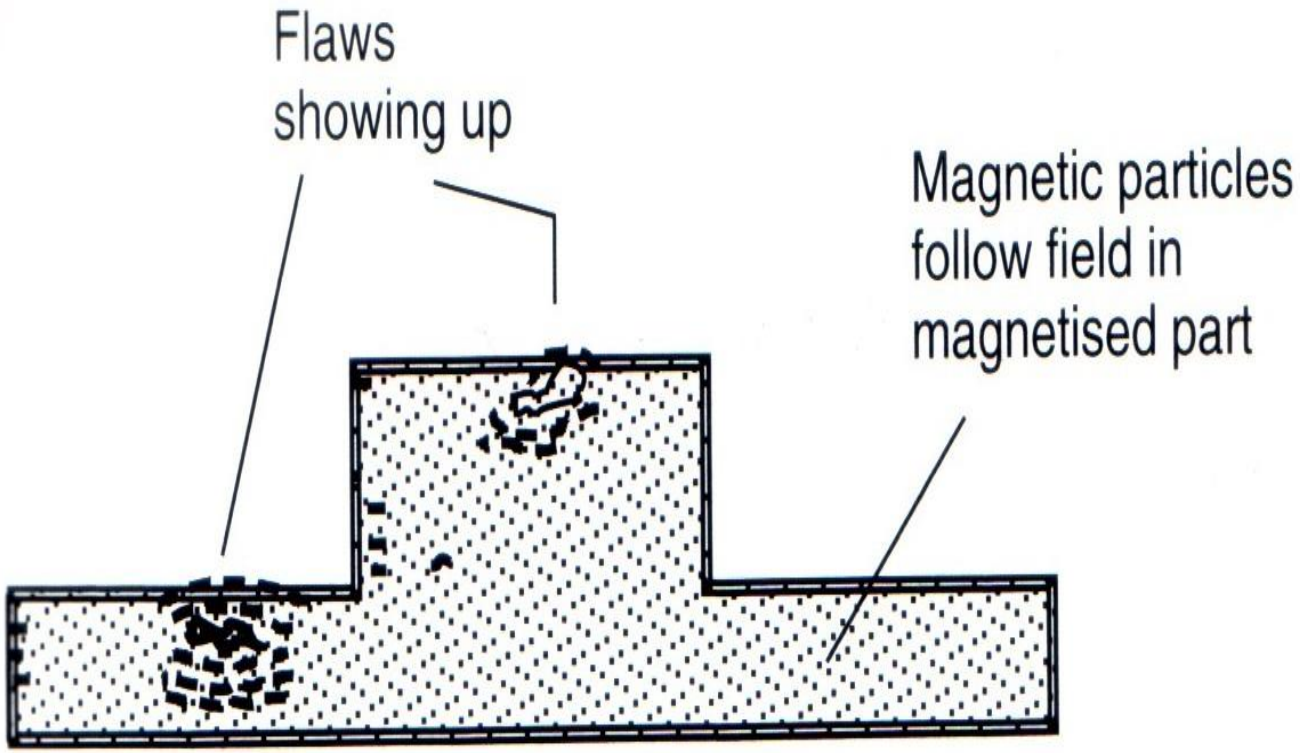
Portable Penetrant System

Stationary Penetrant System

Magnetic particle testing

- Used for ferrous metals.
- Detects flaws close to the surface of the material.
- The component to be tested must first be magnetized.
- Magnetic particles which can be dry or in solution are sprinkled onto the test piece.
- The particles stick to the magnetic field and flaws can be inspected visually by examining the pattern to see if it has been distorted.
- The component must be demagnetized after testing.

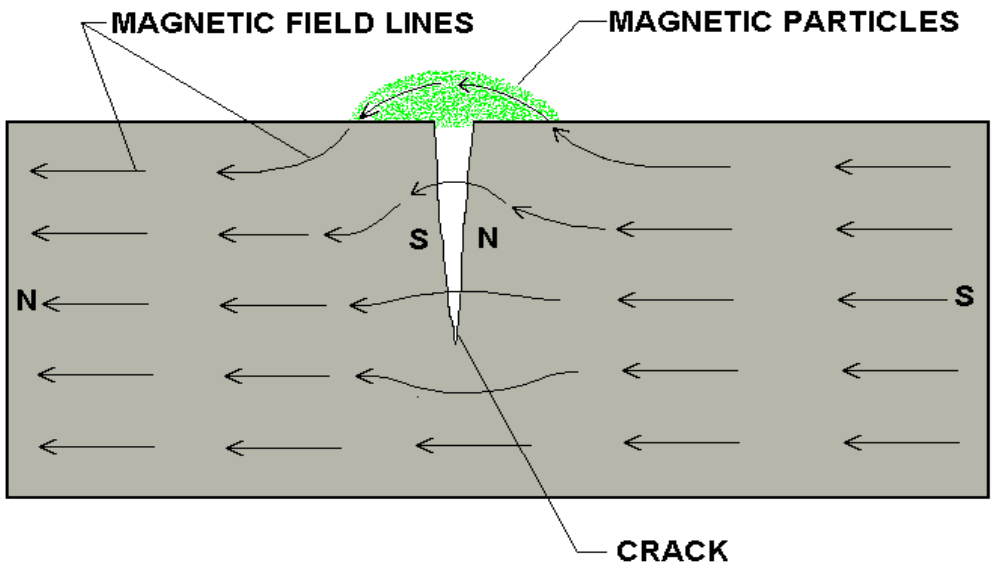
Detection of flaws by magnetic particles



Flaws which are near the surface are more likely to be detected because the distorted magnetic field shows up in the magnetic particle pattern

Magnetic Particle Inspection

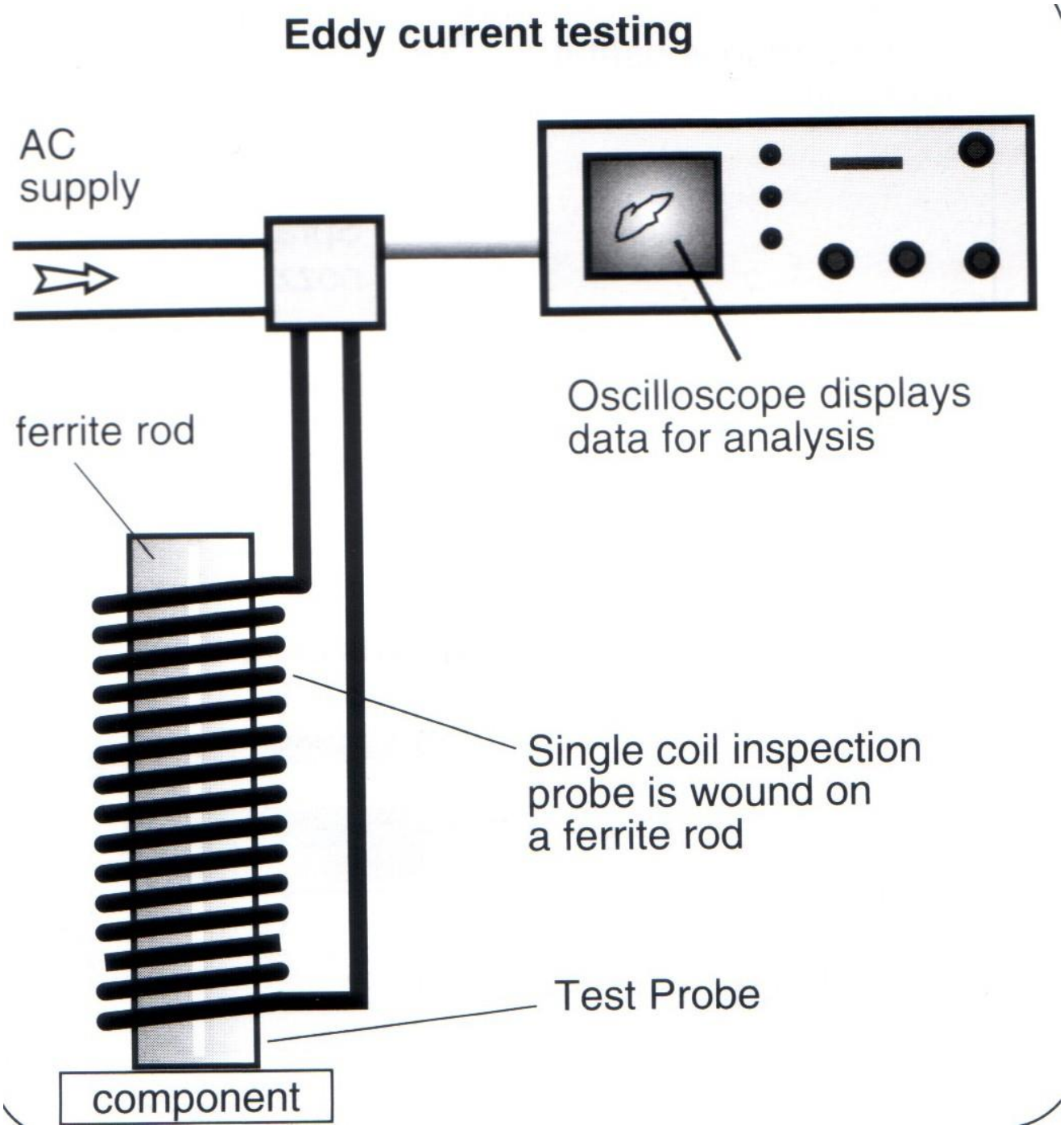
The part is magnetized. Finely milled iron particles coated with a dye pigment are then applied to the specimen. These particles are attracted to magnetic flux leakage fields and will cluster to form an indication directly over the discontinuity. This indication can be visually detected under proper lighting conditions.



Eddy current testing

- Used for non-ferrous metals
- A.C. current is passed through the coil.
- The test piece is passed under the coil causing secondary currents called eddy currents to flow through the test piece. This causes a magnetic field to flow in the test piece.
- The flaws are detected on an oscilloscope by measuring a change in the magnetic field.

Eddy current testing



Ultrasonic testing

Ultrasonic Sound waves are bounced off the component and back to a receiver. If there is a change in the time taken for the wave to return this will show a flaw. This is similar to the operation of a sonar on a ship.

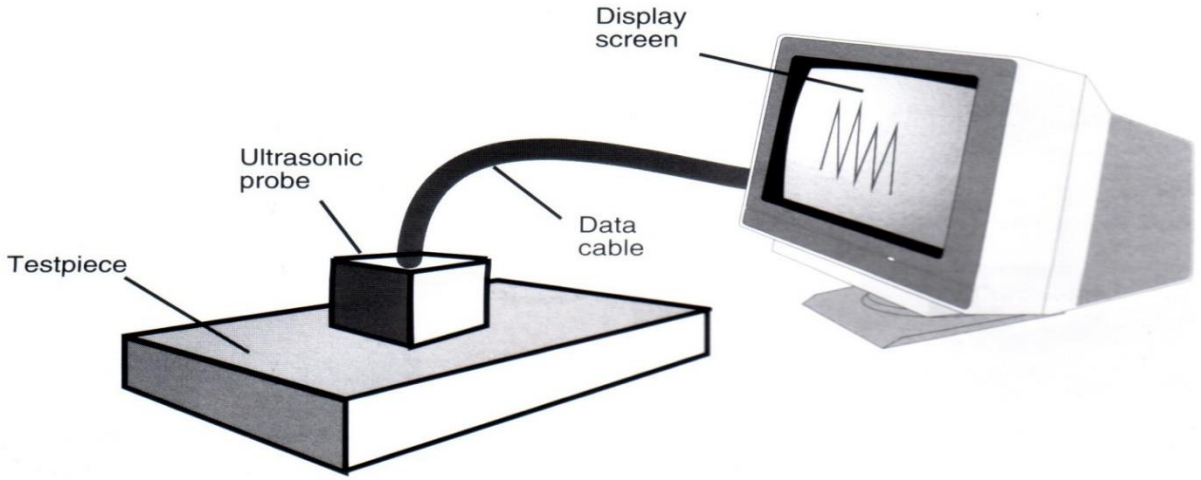
Operation.

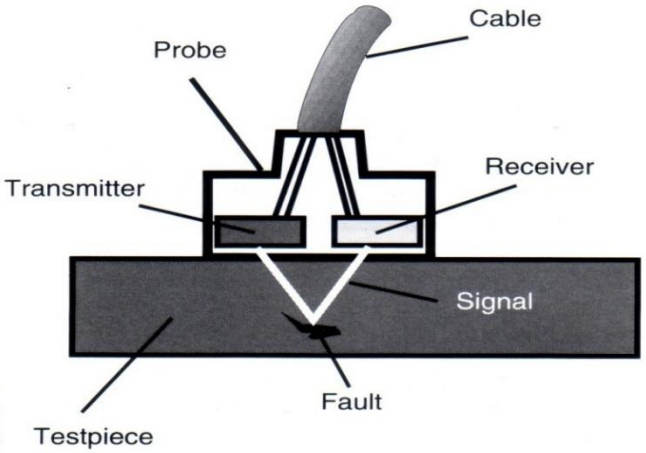
1. The ultrasonic probe sends the sound wave through the piece.
2. The sound wave bounces off the piece and returns.
3. The results are then placed on the display screen in the form of peaks.
4. Where the peaks fluctuate this will show a fault in the piece.

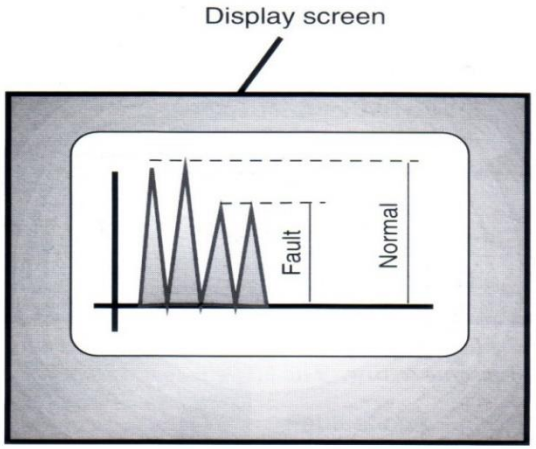
Uses.

- This is generally used to find internal flaws in large forgings, castings and in weld inspections.

Ultrasonic testing







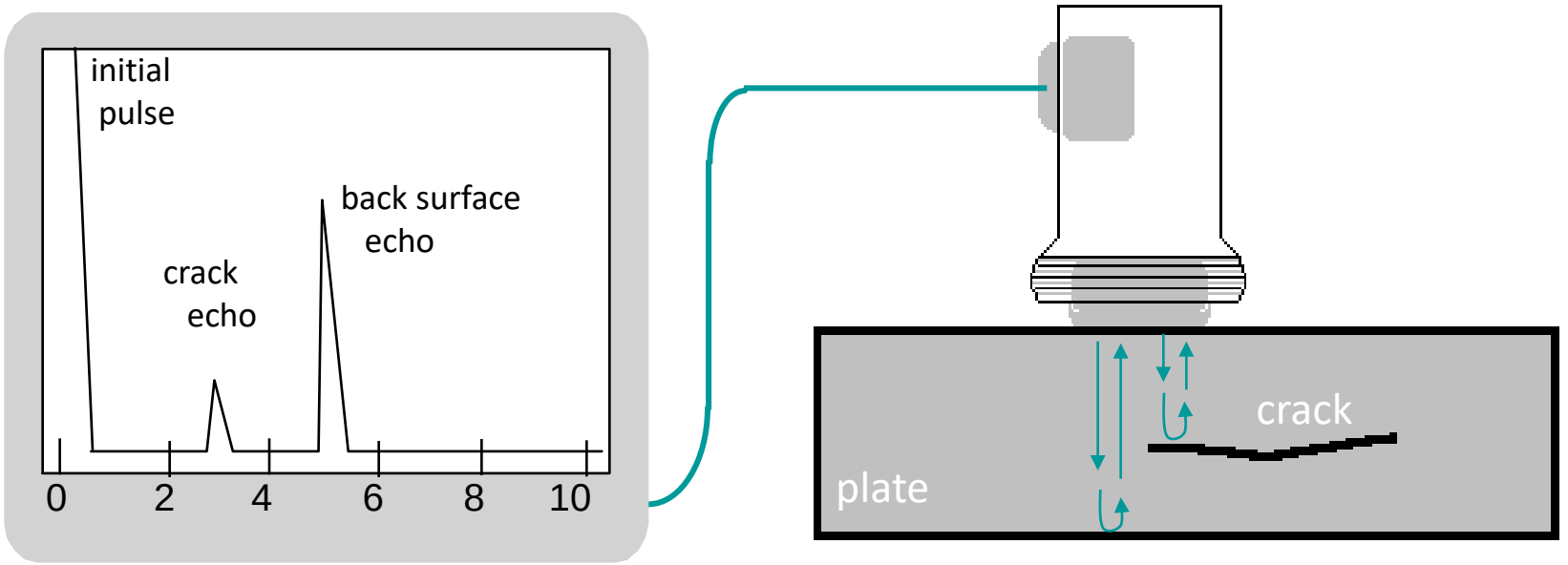
The first two high traces or blips indicate the full thickness of the testpiece while the two short blips show the presence of a fault

The probe may be of the split type where the transmitter is held on one side of the component under test and the receiver is held on the opposite side

Ultrasonic Inspection (Pulse-Echo)

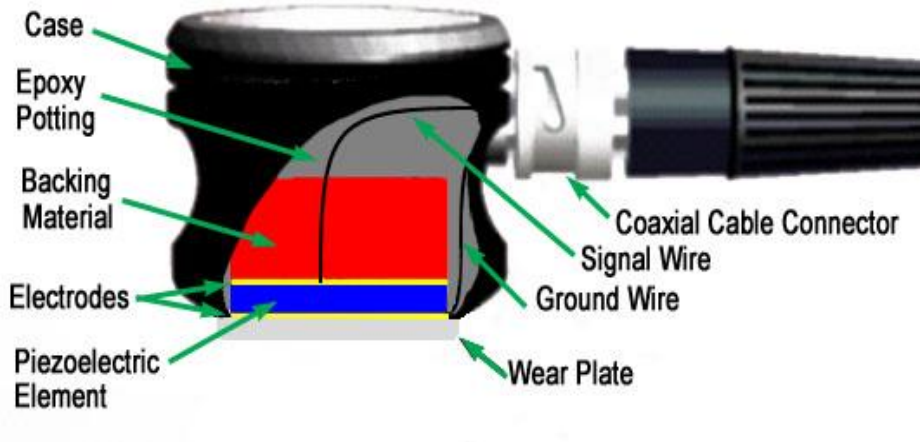
High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.



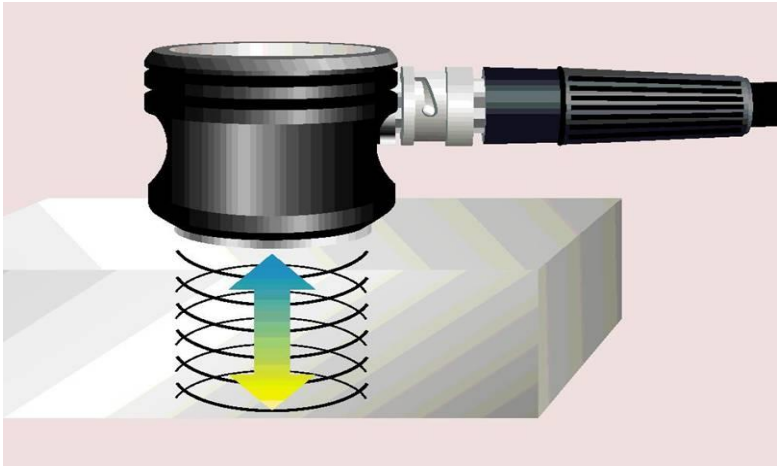
Oscilloscope, or
flaw detector
screen

Ultrasonic Inspection (Pulse-Echo)



A piezoelectric element in the transducer converts electrical energy into mechanical vibrations (sound), and vice versa.

The transducer is capable of both transmitting and receiving sound energy.



Ultrasonic Inspection (Pulse-Echo)

Advantages

- It is sensitive to both surface and subsurface discontinuities.
- Depth of penetration for flaw detection or measurement is superior to other NDT.
- Only single-sided access is needed when the pulse-echo technique is used.
- Highly accurate in determining reflector position and estimating size and shape.
- Minimal part preparation is required.
- Electronic equipment provides instantaneous results.
- Detailed images can be produced with automated systems.
- It has other uses, such as thickness measurement, in addition to flaw detection.

Ultrasonic Inspection (Pulse-Echo)

Limitations

- Surface must be accessible to transmit ultrasound.
- Skill and training is more extensive than with some other methods.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
- Cast iron and other coarse grained materials are difficult to inspect due to low sound transmission and high signal noise.
- Linear defects oriented parallel to the sound beam may go undetected.

Ultrasonic Imaging

Radiography (X-ray) Testing

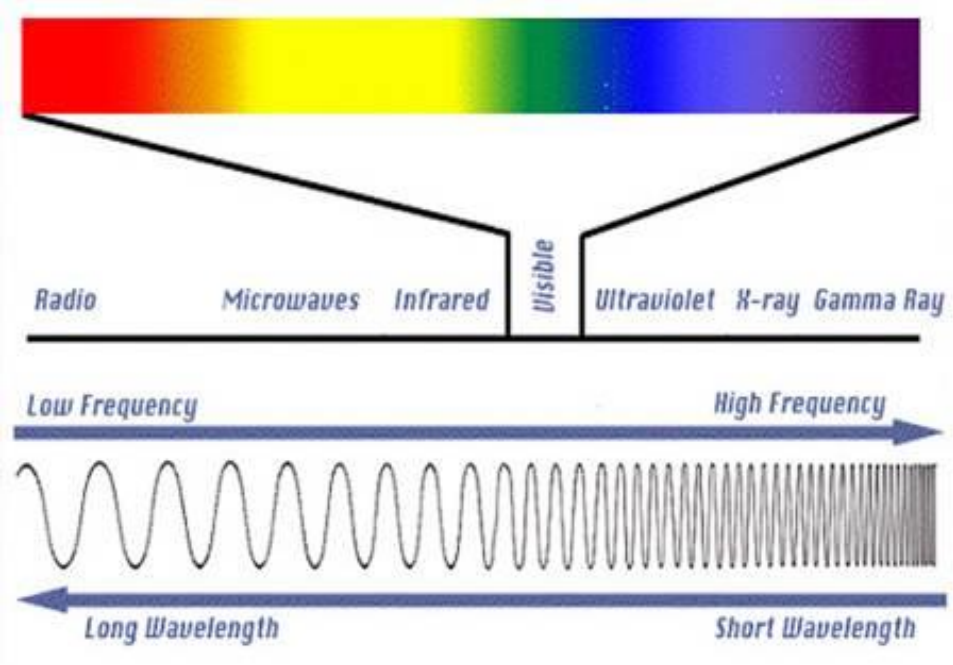
1. The x-ray are released by heating the cathode.
2. They are then accelerated by the D.C. current and directed onto the piece by the tungsten anode.
3. The x-rays then pass through the test piece onto an x-ray film which displays the results.
4. The x-rays cannot pass through the faults as easily making them visible on the x-ray film.

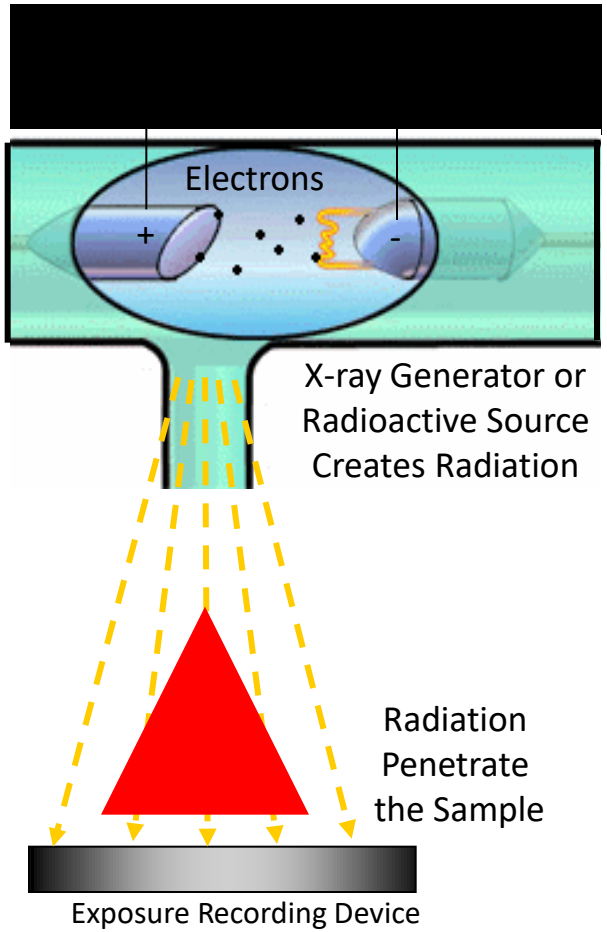
Uses.

- This is a test generally used to find internal flaws in materials. It is used to check the quality of welds, for example, to find voids or cracks.

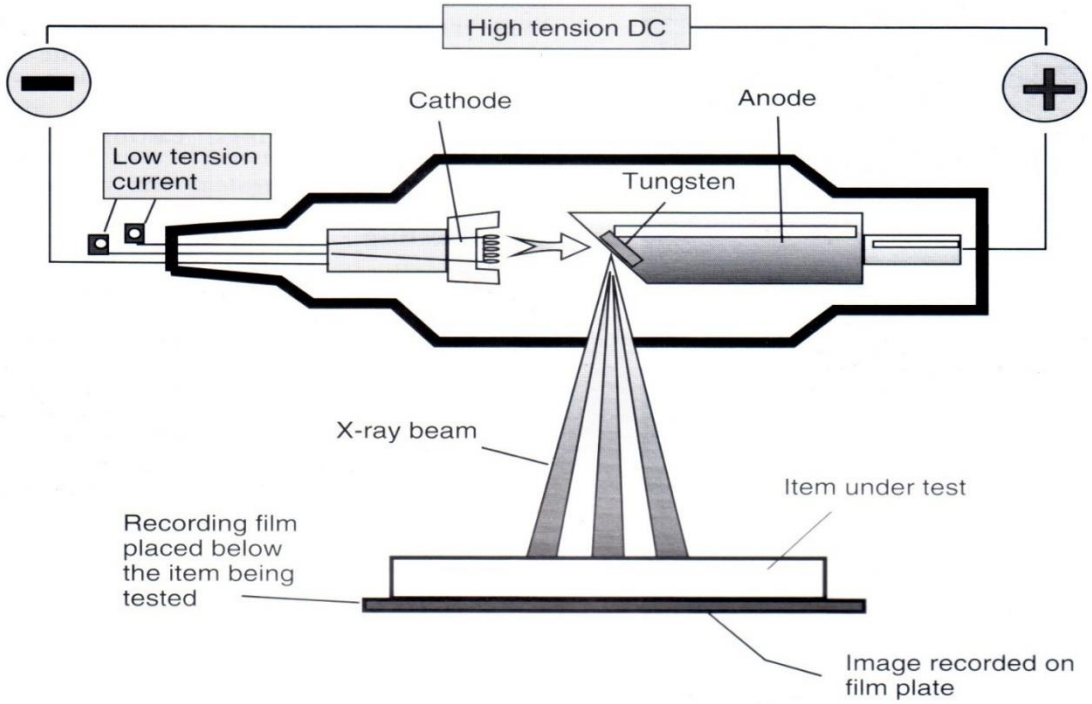
Radiography

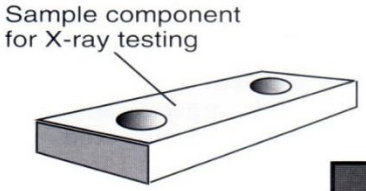
The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.





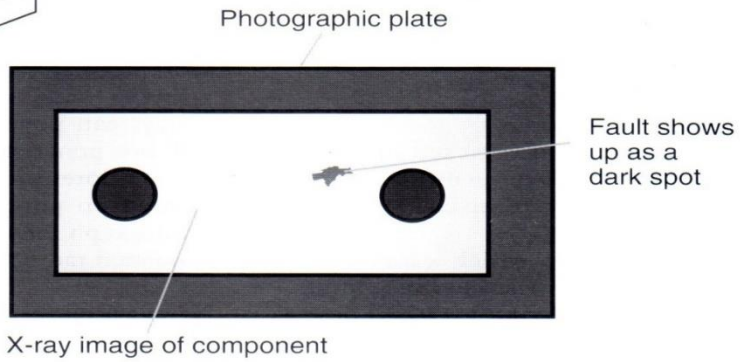
Radiography or X-ray testing



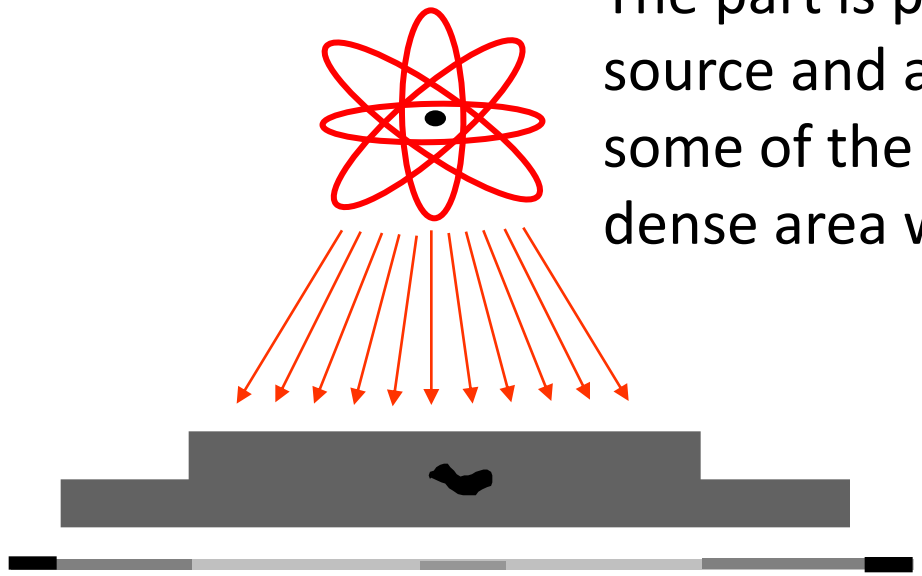


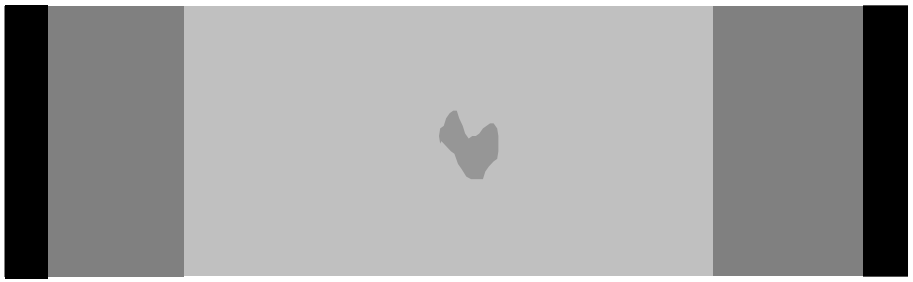
A simulated X-ray photo or radiograph of the component is shown on the right

What an X-ray image or radiograph looks like



Film Radiography





Top view of developed film

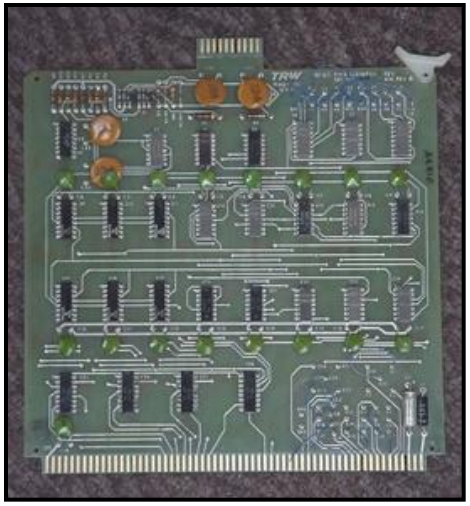
The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.

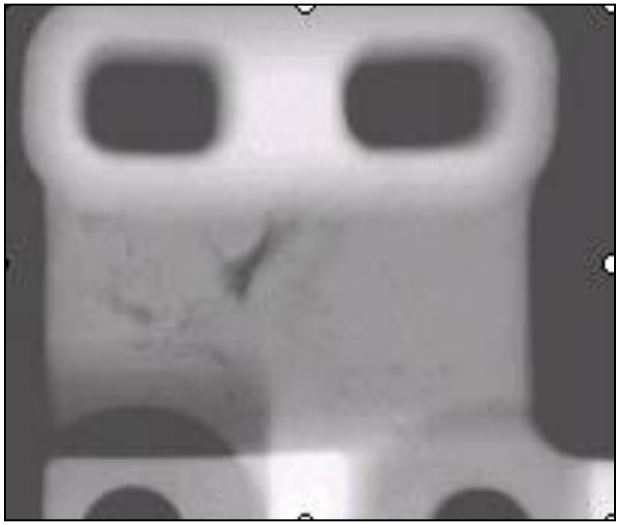
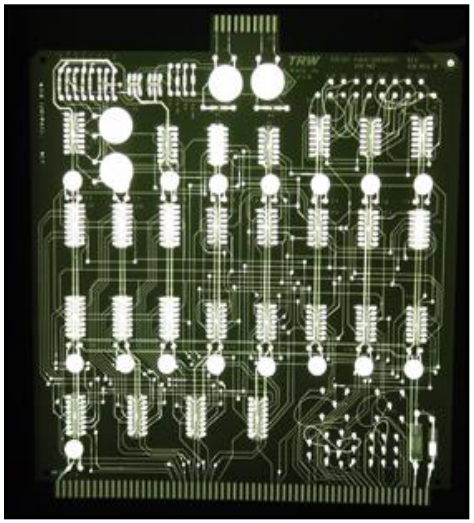
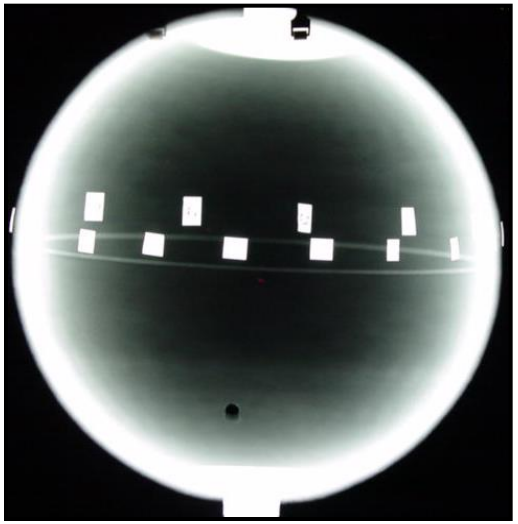
The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

= less exposure

= more exposure

Radiographic Images

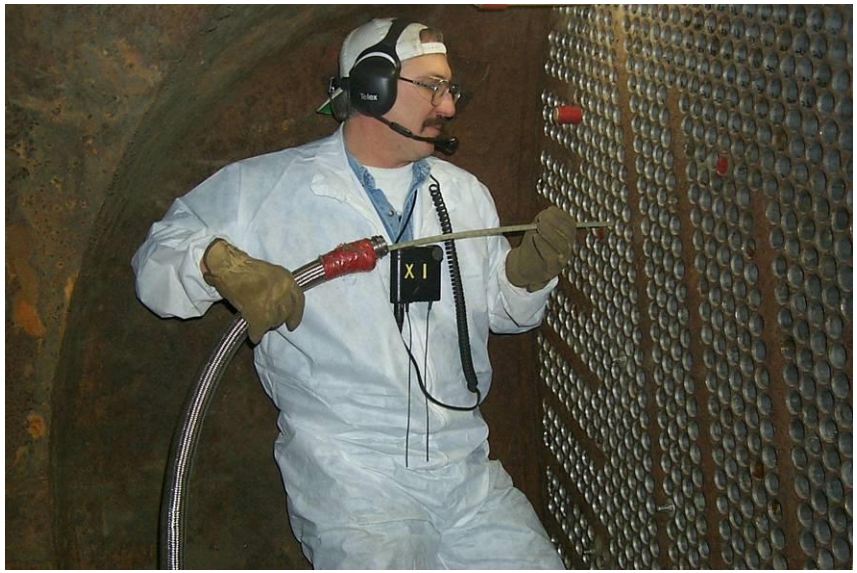




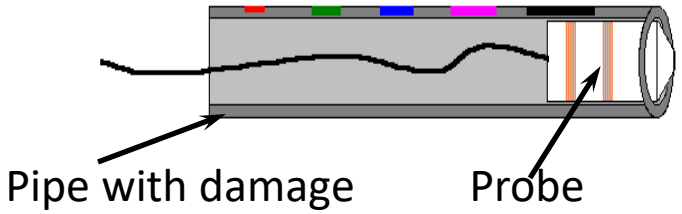
Inspection For
In-Service Damage

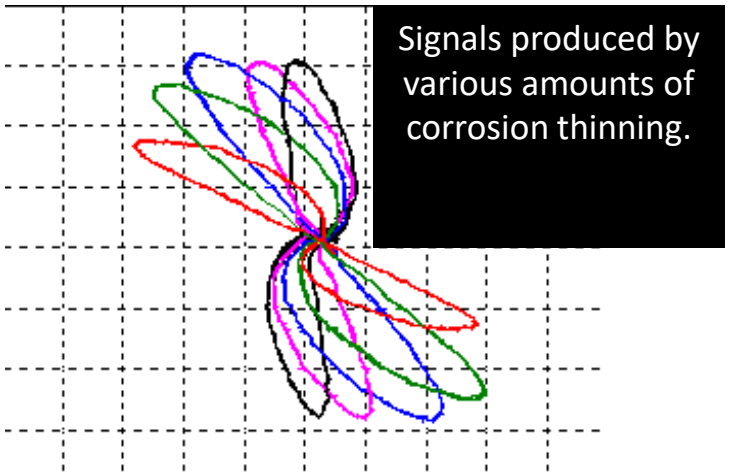
- Cracking
- Corrosion
- Erosion/Wear
- Heat Damage
- etc.

Power Plant Inspection

Periodically, power plants are shutdown for inspection. Inspectors feed eddy current probes into heat exchanger tubes to check for corrosion damage.

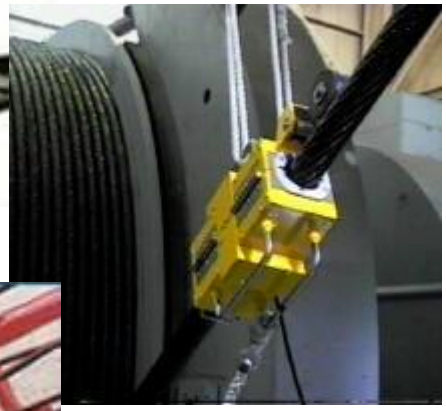






Wire Rope Inspection

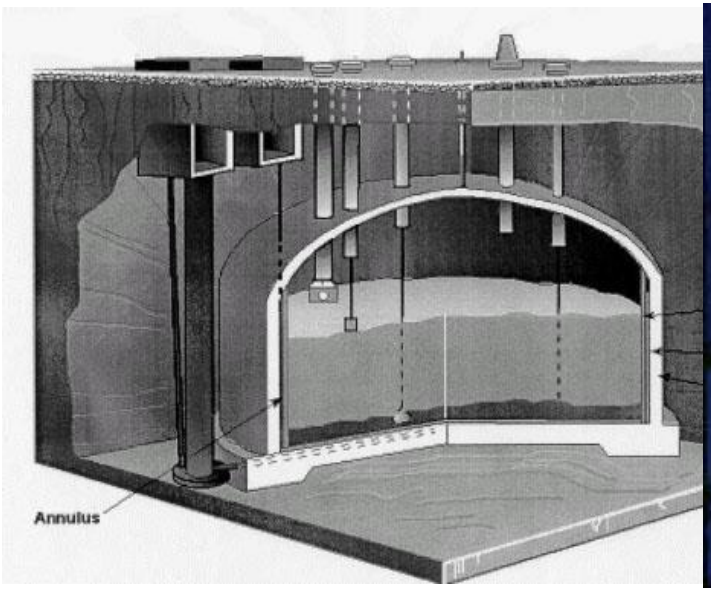
Electromagnetic devices and visual inspections are used to find broken wires and other damage to the wire rope that is used in chairlifts, cranes and other lifting devices.



Storage Tank Inspection

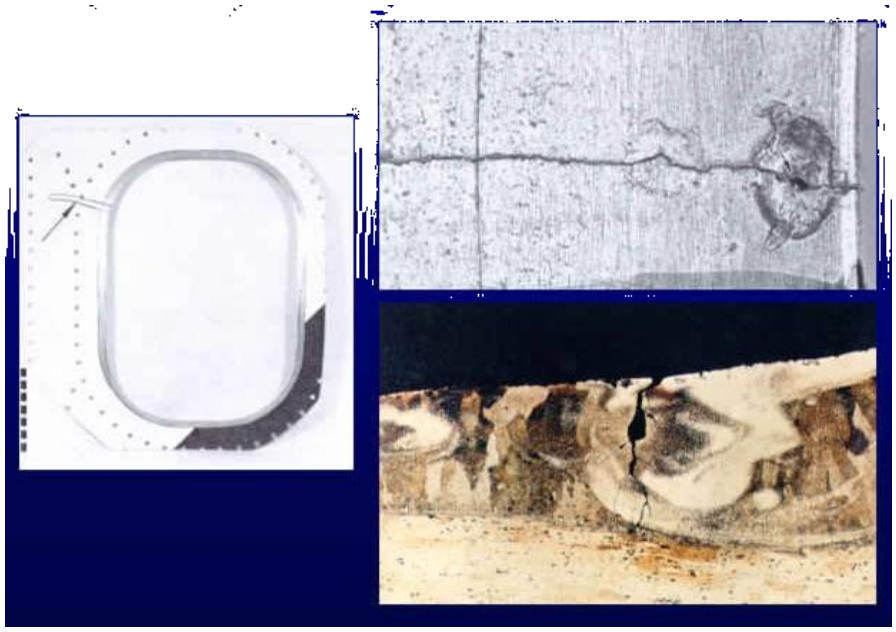
Robotic crawlers use ultrasound to inspect the walls of large above ground tanks for signs of thinning due to corrosion.

Cameras on long arms are used to inspect underground storage tanks for damage.



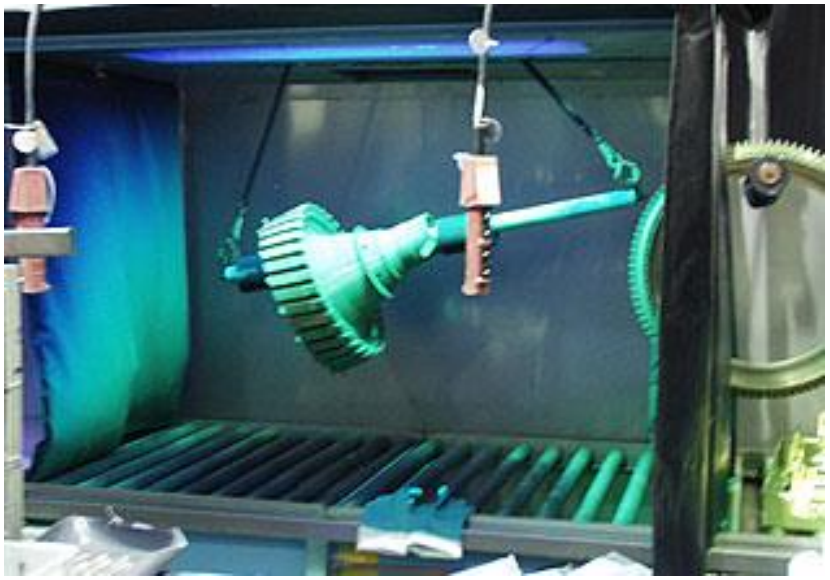
Aircraft Inspection

- ND T is used extensively during the manufacturing of aircraft.
- NDT is also used to find cracks and corrosion damage during operation of the aircraft.
- A fatigue crack that started at the site of a lightning strike is shown below.



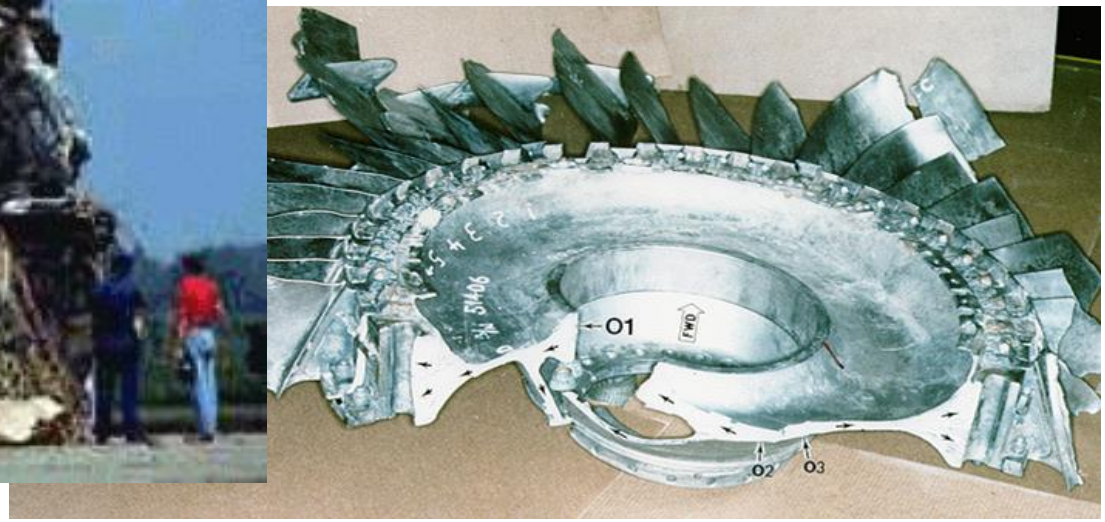
Jet Engine Inspection

- Aircraft engines are overhauled after being in service for a period of time.
- They are completely disassembled, cleaned, inspected and then reassembled.
- Fluorescent penetrant inspection is used to check many of the parts for cracking.



Crash of United Flight 232
Sioux City, Iowa, July 19, 1989

A defect that went undetected in an engine disk was responsible for the crash of United Flight 232.

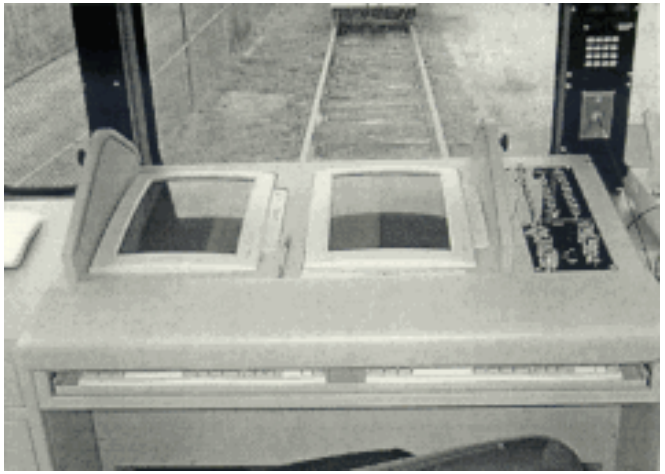


Pressure Vessel Inspection

The failure of a pressure vessel can result in the rapid release of a large amount of energy. To protect against this dangerous event, the tanks are inspected using radiography and ultrasonic testing.

Rail Inspection

Special cars are used to inspect thousands of miles of rail to find cracks that could lead to a derailment.



Bridge Inspection

- The US has 578,000 highway bridges.
- Corrosion, cracking and other damage can all affect a bridge's performance.
- The collapse of the Silver Bridge in 1967 resulted in loss of 47 lives.
- Bridges get a visual inspection about every 2 years.
- Some bridges are fitted with acoustic emission sensors that "listen" for sounds of cracks growing.

Pipeline Inspection

NDT is used to inspect pipelines to prevent leaks that could damage the environment. Visual inspection, radiography and electromagnetic testing are some of the NDT methods used.


Photo Courtesy of Inuktun


Photo Courtesy of Yxlon International

For More Information on NDT

The Collaboration for NDT Education

www.ndt-ed.org

The American Society for Nondestructive Testing

www.asnt.org

Thank You