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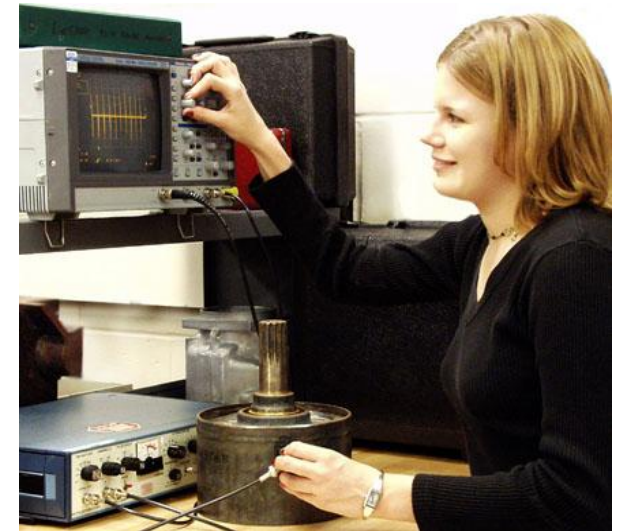
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COIMBATORE-641 035, TAMIL NADU



Department of Aerospace Engineering

Introduction to Non-destructive Testing



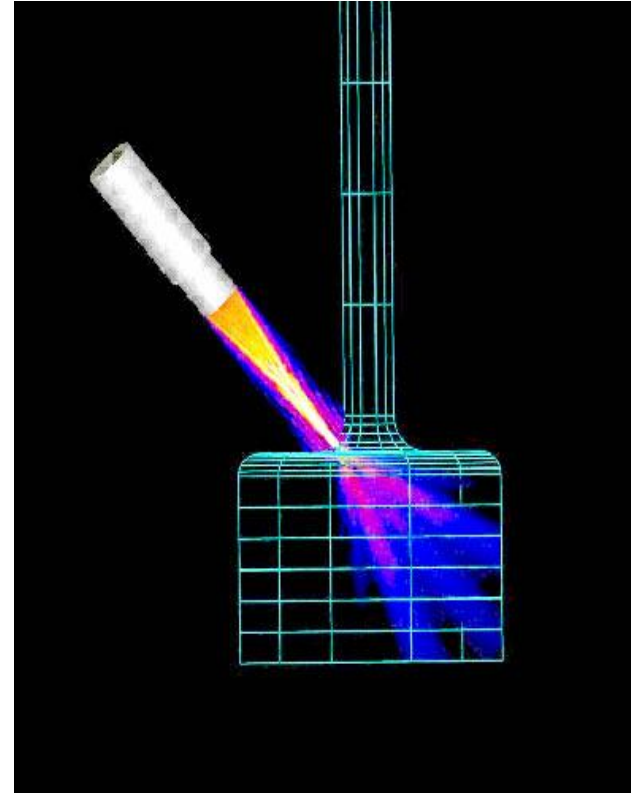
19AST202 AIRCRAFT PRODUCTION TECHNOLOGY

ADDITIVE MANUFACTURING IN AEROSPACE

Prepared by Dr.M .Subramanian Professor & Head of Aerospace Engineering

Definition of NDT

The use of noninvasive techniques to determine the integrity of a material, component or structure or quantitatively measure some characteristic of an object.



i.e. Inspect or measure without doing harm.

Methods of NDT

Visual

Tap Testing

Microwave

Thermography

Magnetic Particle

X-ray

Acoustic Microscopy

Acoustic Emission

Magnetic Measurements

Liquid Penetrant

Ultrasonic

Replication

Flux Leakage

Laser Interferometry

Eddy Current

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



Fluorescent penetrant indication

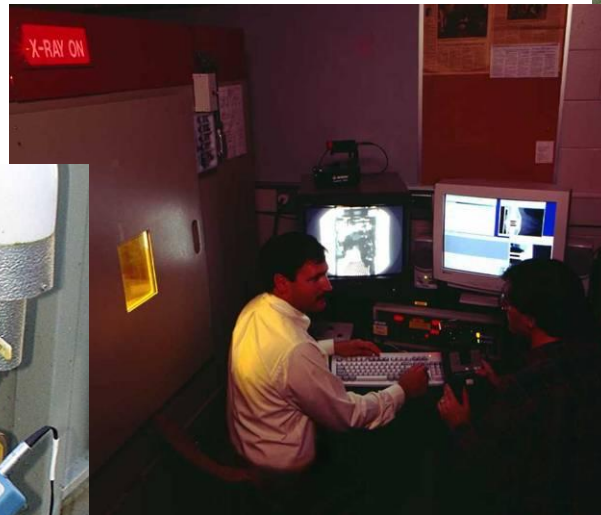
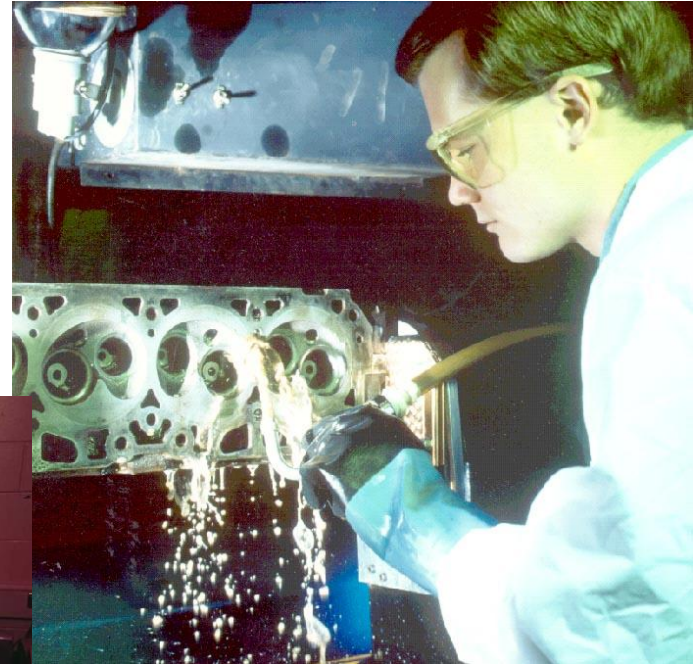
When are NDE Methods Used?

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.

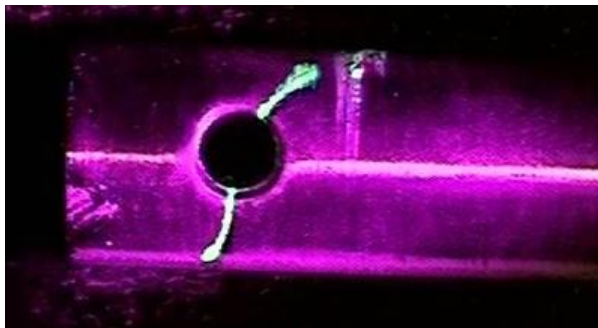
Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.



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

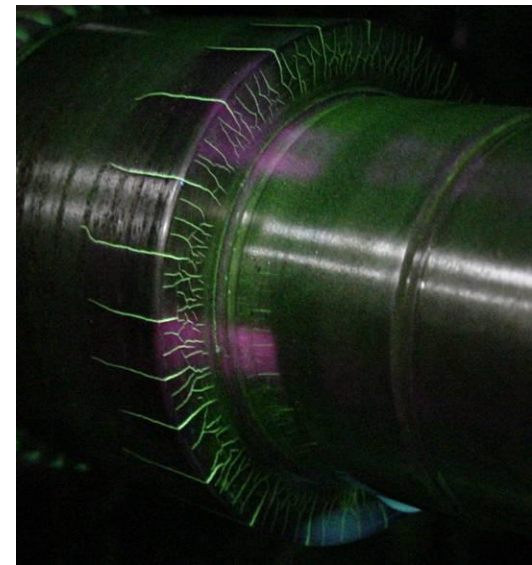
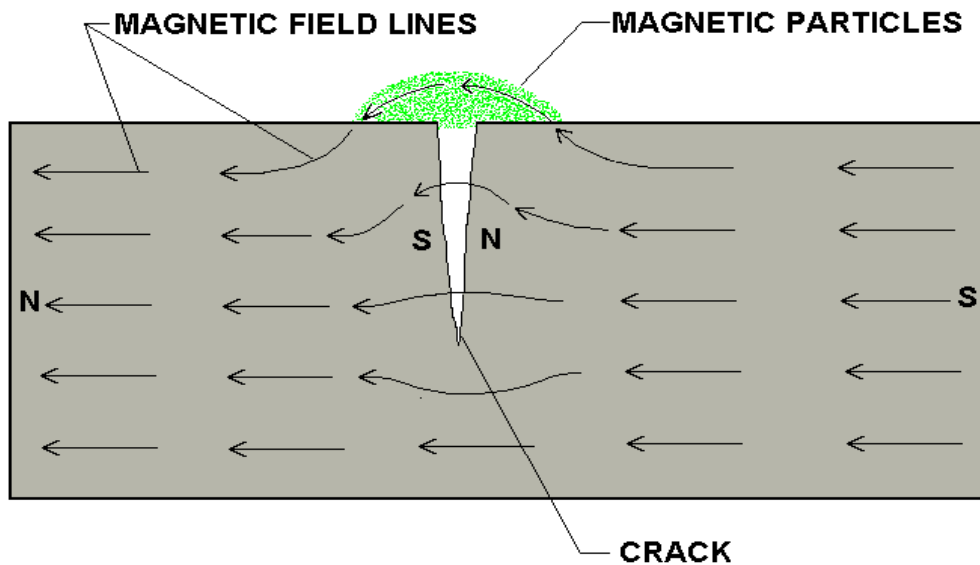
Liquid Penetrant Inspection

- 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.

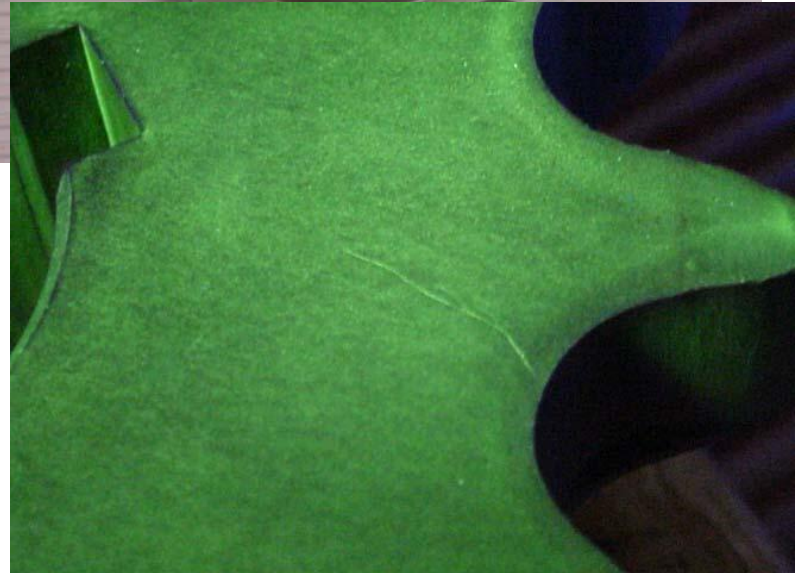
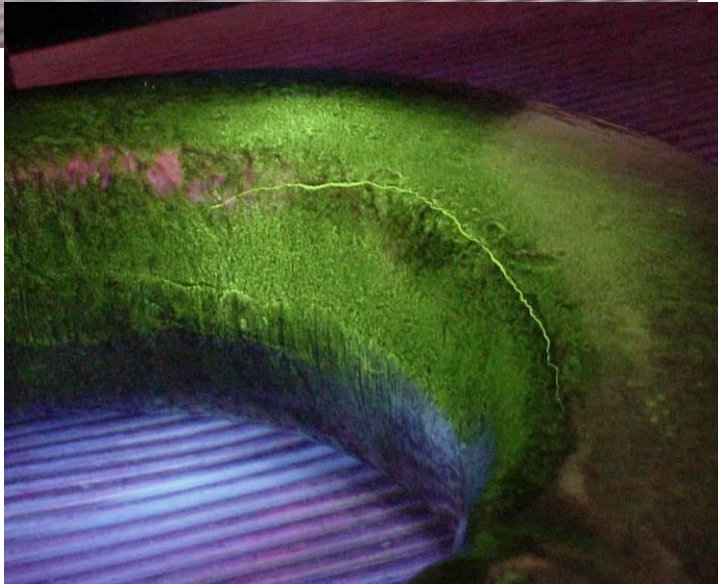


Magnetic Particle Inspection

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.

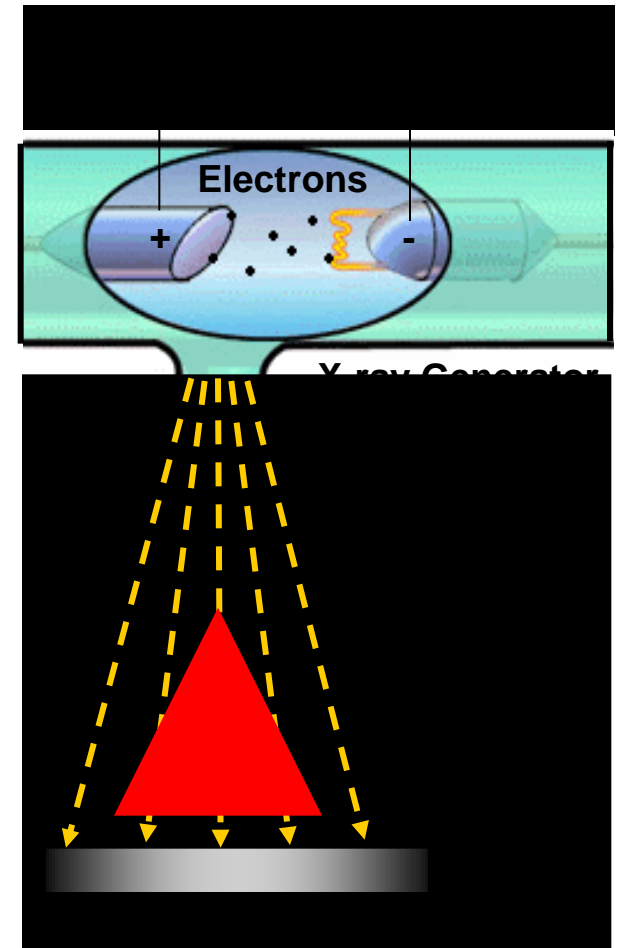
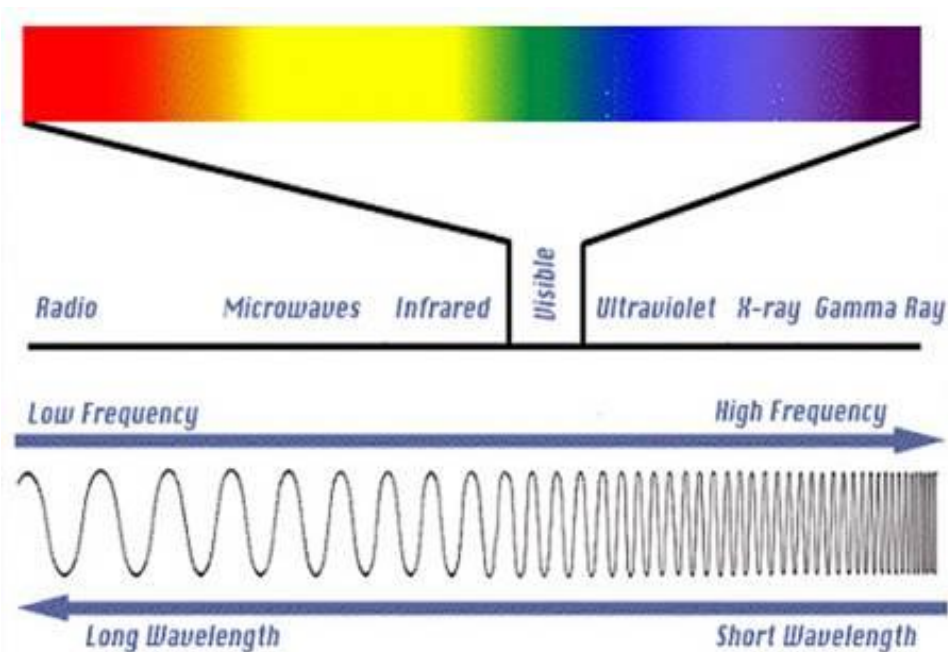


Magnetic Particle Crack Indications



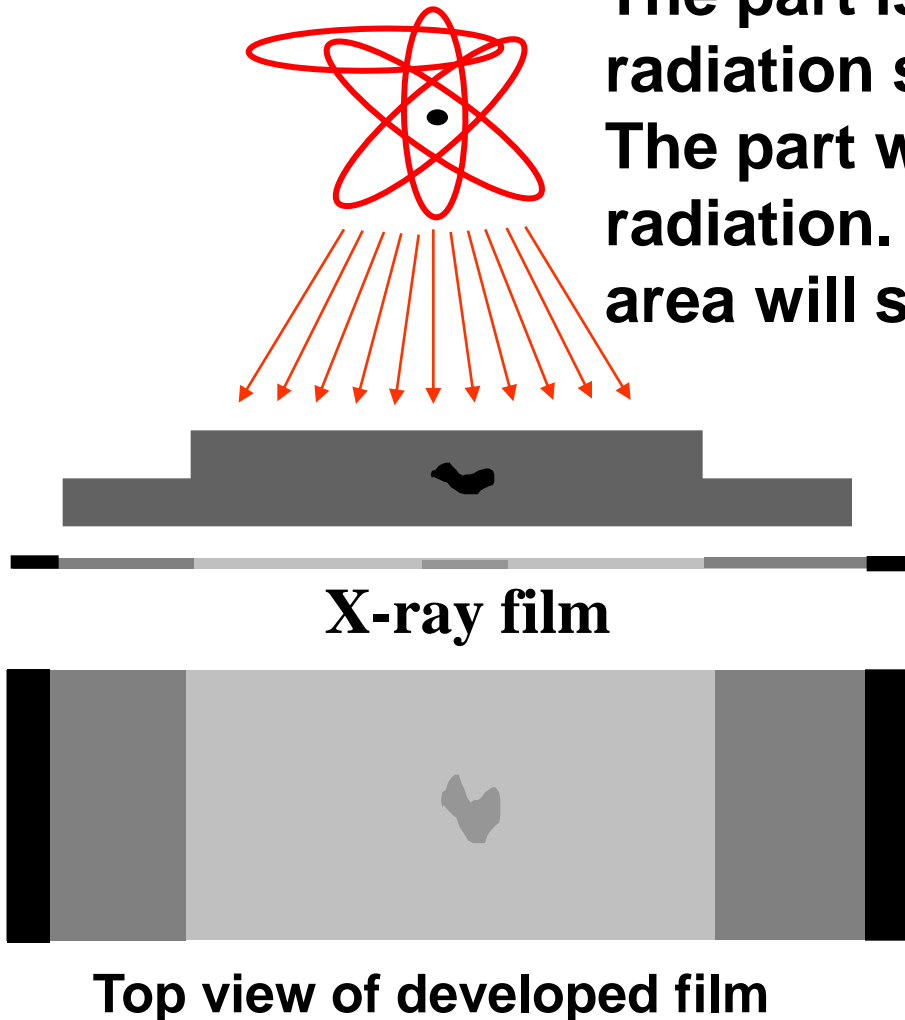
Radiography

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.



Film Radiography

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.

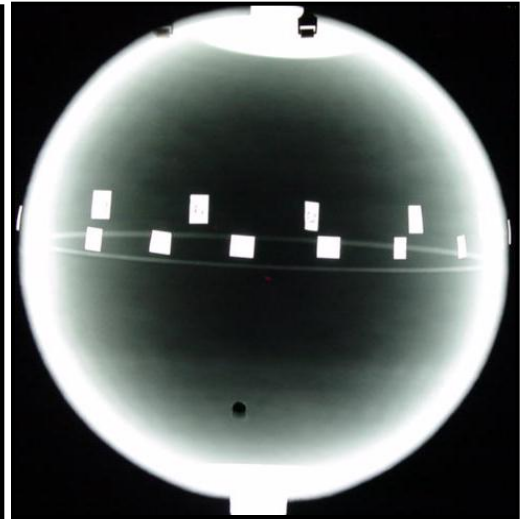
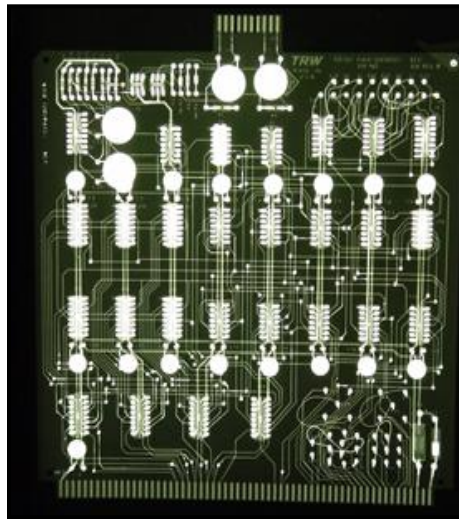
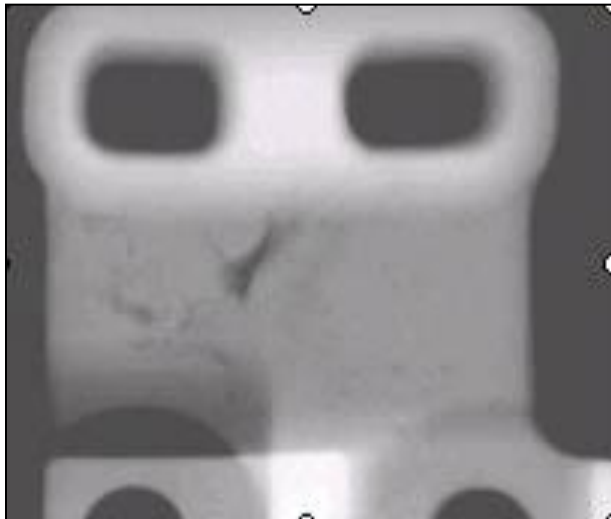
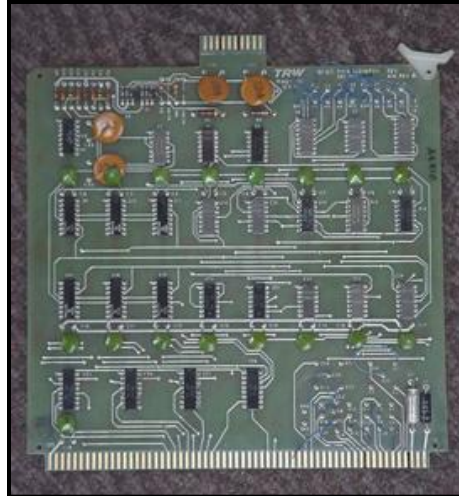


= less exposure

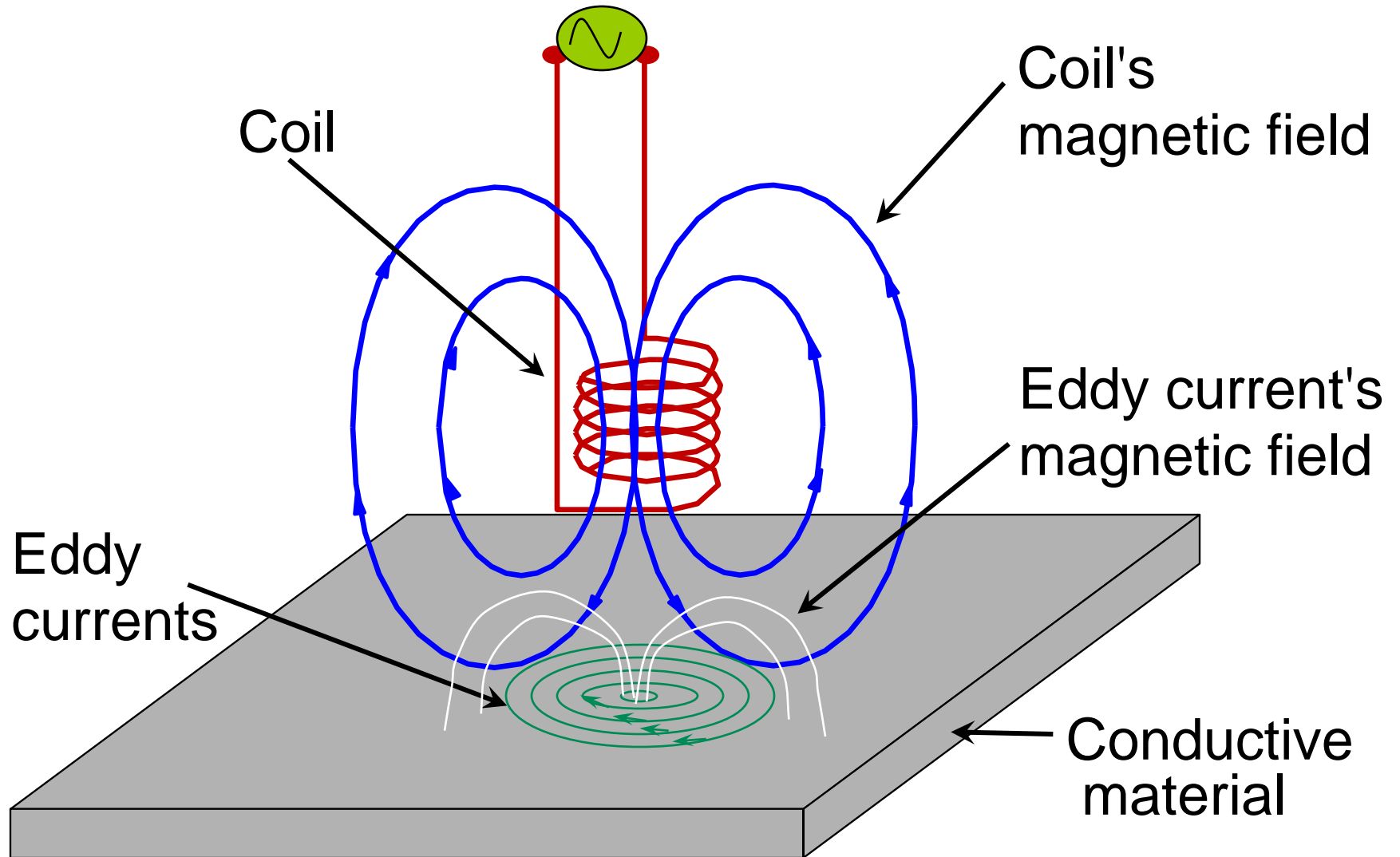


= more exposure

Radiographic Images



Eddy Current Testing



Eddy Current Testing

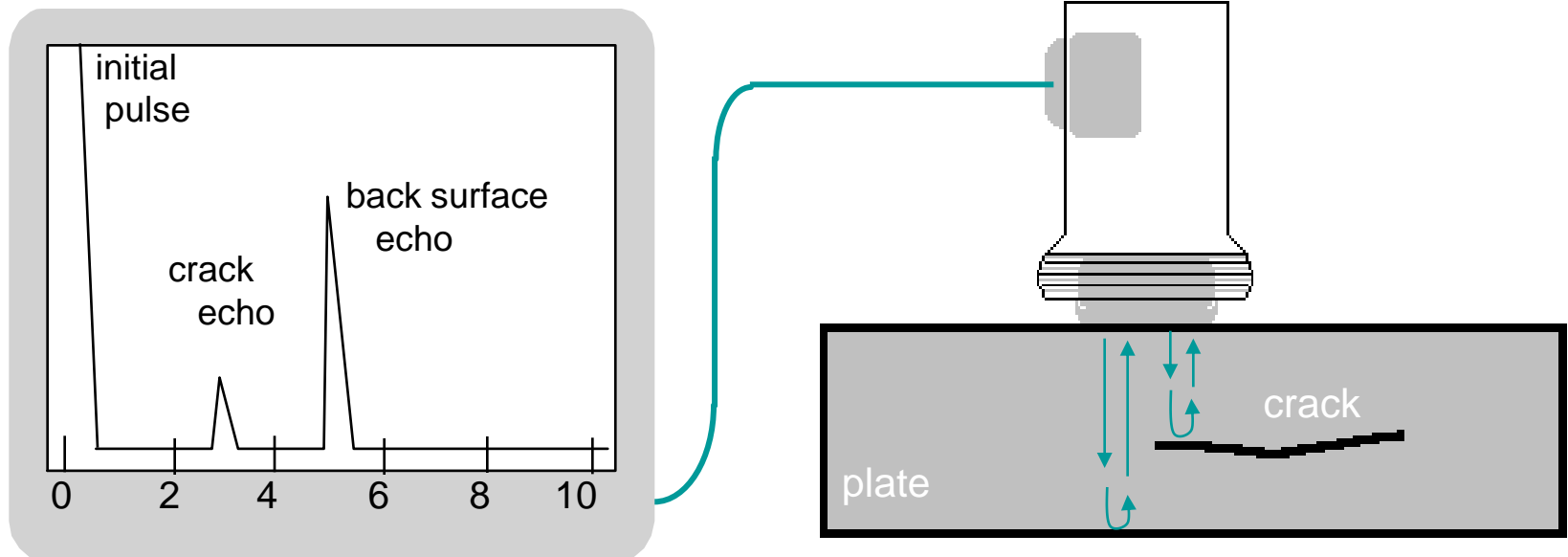
Eddy current testing is particularly well suited for detecting surface cracks but can also be used to make electrical conductivity and coating thickness measurements. Here a small surface probe is scanned over the part surface in an attempt to detect a crack.



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.



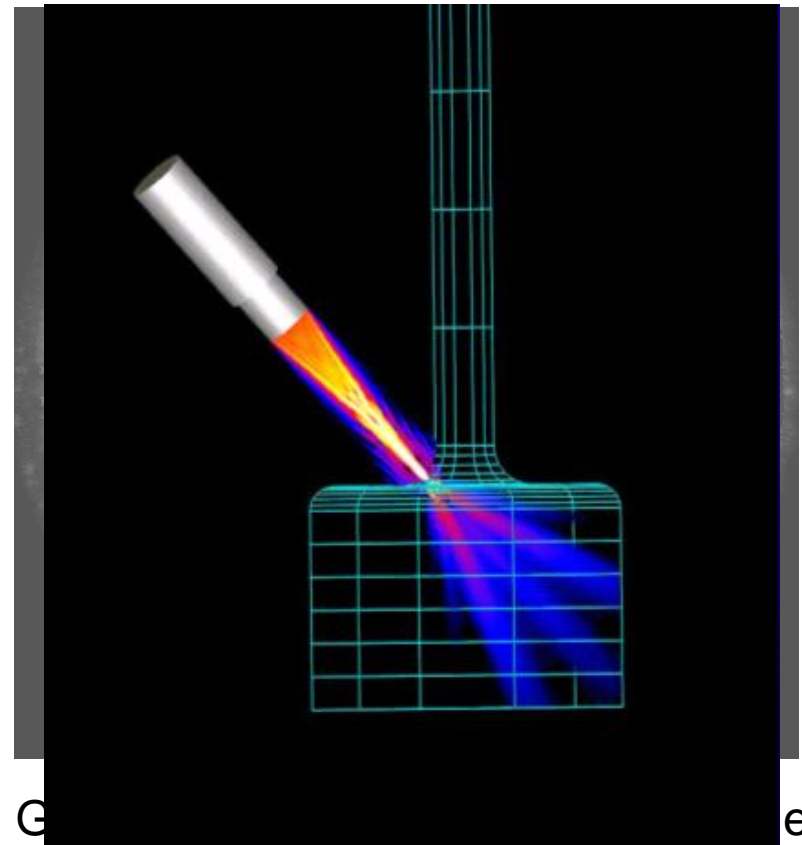
Oscilloscope, or flaw detector screen

Ultrasonic Imaging

High resolution images can be produced by plotting signal strength or time-of-flight using a computer-controlled scanning system.



Gray scale image produced using the sound reflected from the front surface of the coin



Gray scale image produced using the sound reflected from the back surface of the coin (inspected from "heads" side)

Common Application of NDT

- Inspection of Raw Products
- Inspection Following Secondary Processing
- In-Services Damage Inspection

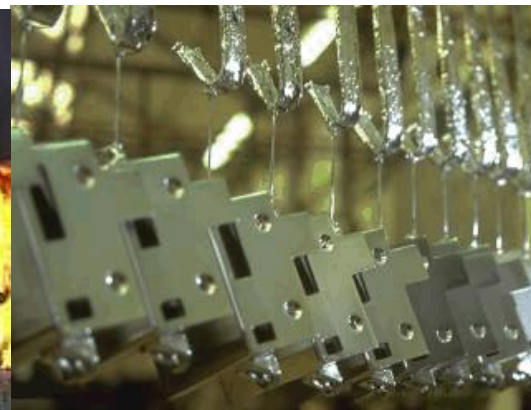
Inspection of Raw Products

- Forgings,
- Castings,
- Extrusions,
- etc.



Inspection Following Secondary Processing

- Machining
- Welding
- Grinding
- Heat treating
- Plating



Inspection For In-Service Damage

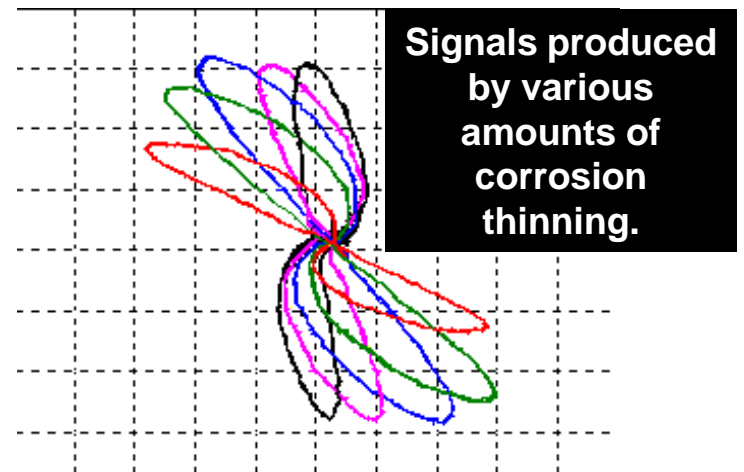
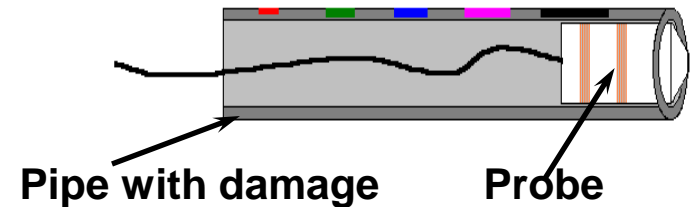
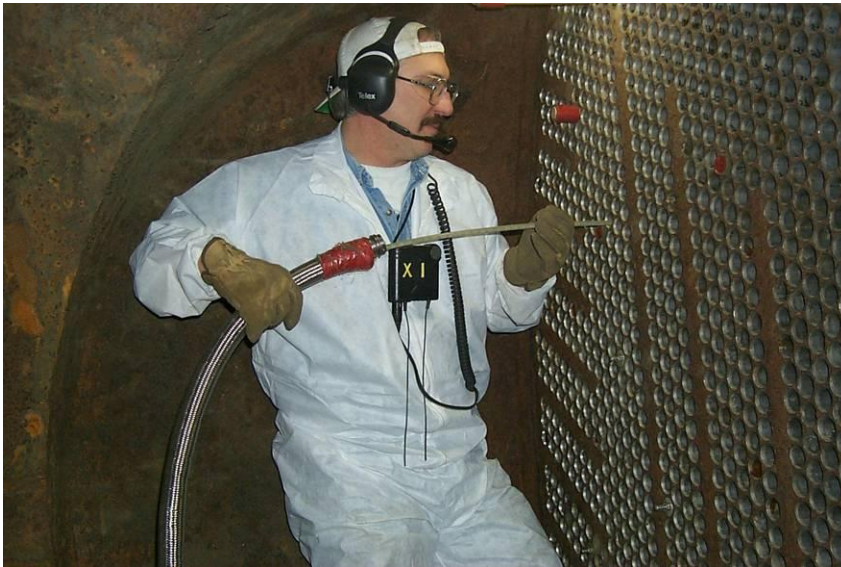
- Cracking
- Corrosion
- Erosion/Wear
- Heat Damage
etc.



Power Plant Inspection

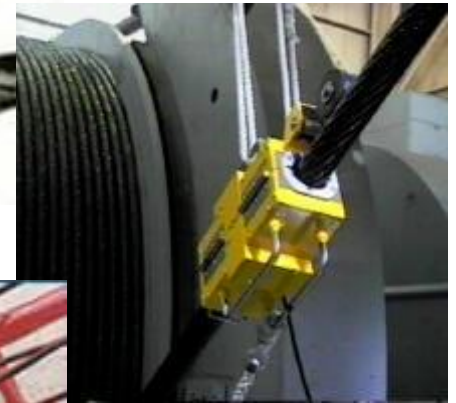
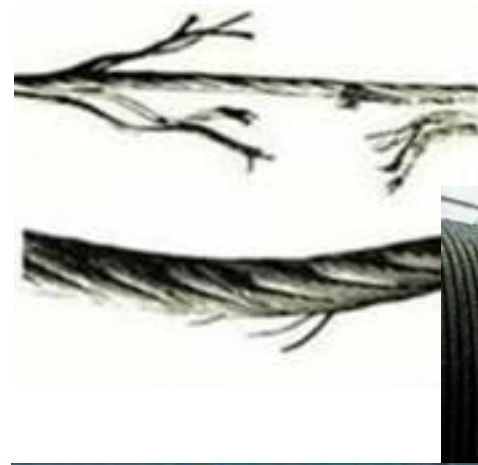


Periodically, power plants are shutdown for inspection. Inspectors feed eddy current probes into heat exchanger tubes to check for corrosion damage.



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.

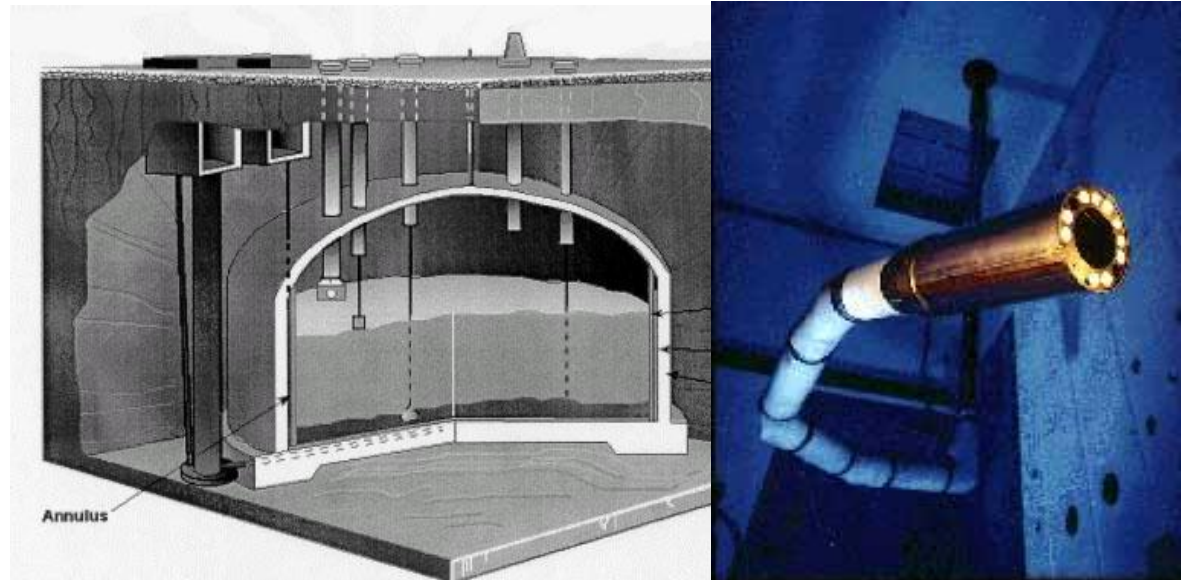


Storage Tank Inspection

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

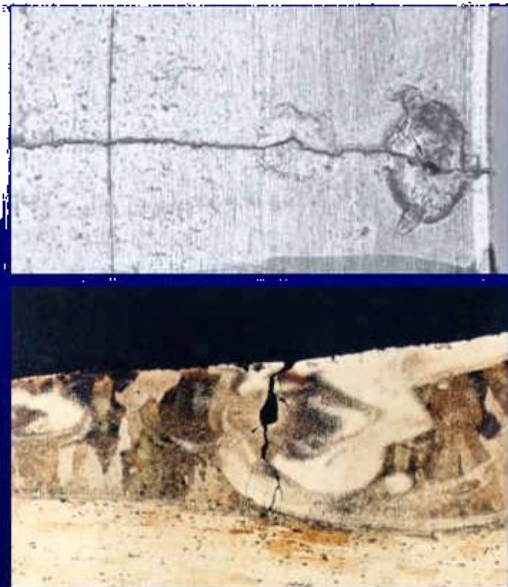
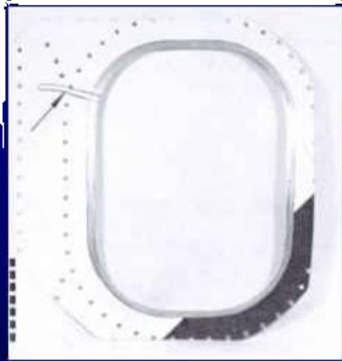


Cameras on long articulating arms are used to inspect underground storage tanks for damage.



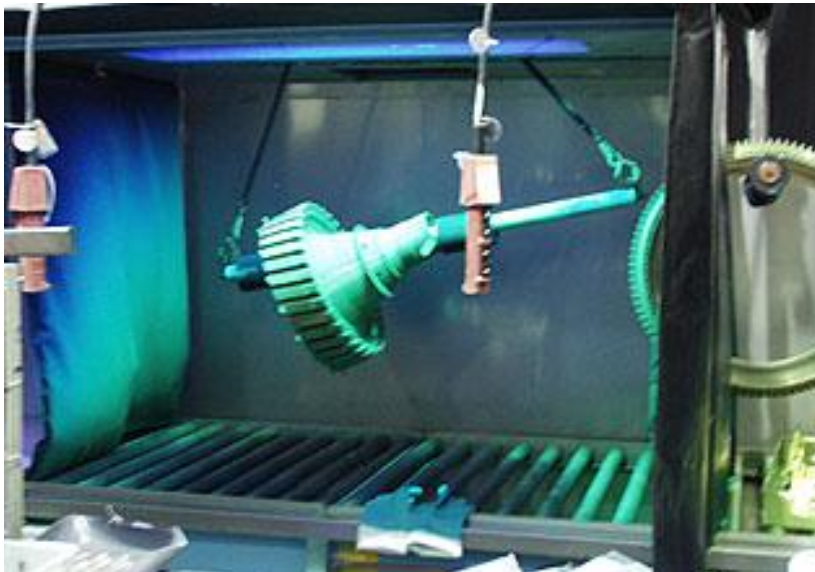
Aircraft Inspection

- Nondestructive testing 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

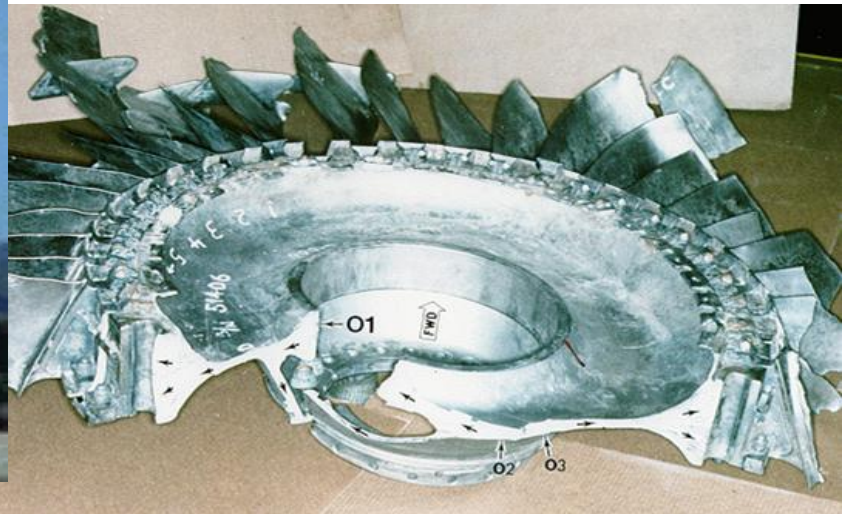
- Aircraft engines are overhauled after being in service for a period of time.
- They are completely disassembled, cleaned, inspected and then reassembled.
- Fluorescent penetrant inspection is used to check many of the parts for cracking.



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.



Magnetic flux leakage inspection. This device, known as a pig, is placed in the pipeline and collects data on the condition of the pipe as it is pushed along by whatever is being transported.

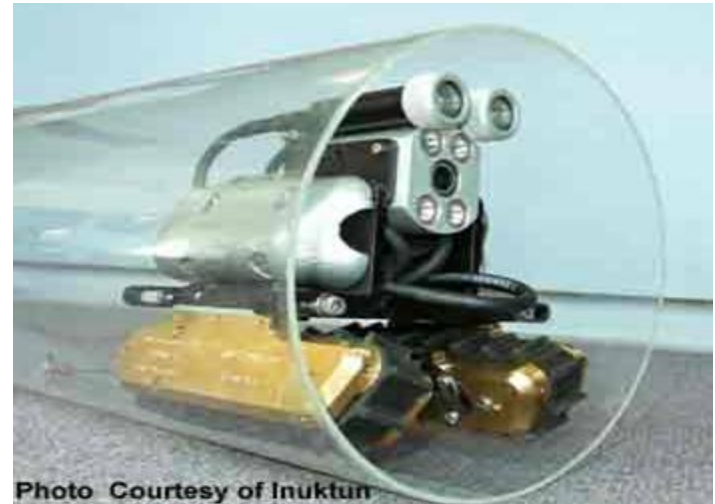


Photo Courtesy of Inuktun

Remote visual inspection using a robotic crawler.



Photo Courtesy of Yxlon International

Radiography of weld joints.

Special Measurements

Boeing employees in Philadelphia were given the privilege of evaluating the Liberty Bell for damage using NDT techniques. Eddy current methods were used to measure the electrical conductivity of the Bell's bronze casing at various points to evaluate its uniformity.



RADIOGRAPHY

Sub assembly Components:

The sub assembly coach components fabricated by fillet welding are taken radiographs, where the load acting areas as prescribed by the relevant drawing and suspected weld area during visual inspection.

MARKING OF RADIOGRAPHIC LOCATION, DIRECTION OF WELD BEAD AND PLACING OF PENETROMETER



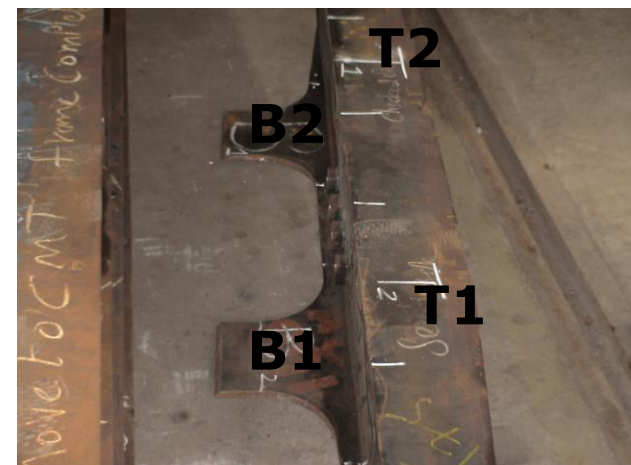
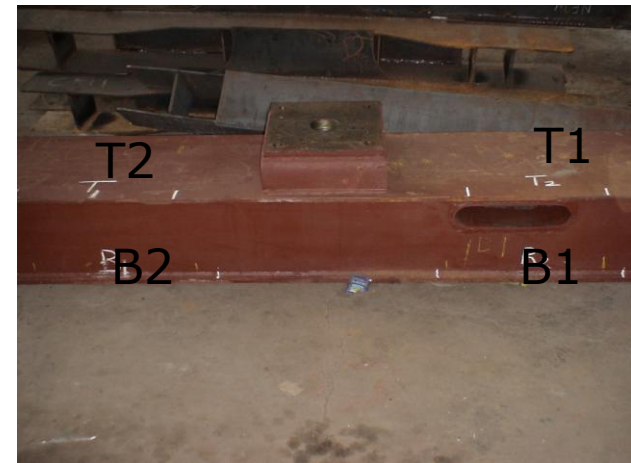
PLACING OF LOADED RADIOGRAPHIC FILM



PLACING OF LEAD SHEET TO AVOID SCATTER RADIATION



Sub-assembly Components



RADIOGRAPHIC STANDARDS FOR EVALUATION OF WELD DEFECTS.

Two type of standards are generally used for evaluation

1. IIW standard
2. ASTM standard

- 1. IIW Standard:

THERE ARE FIVE IIW STANDARDS

- **BLACK** DEFECT FREE
- **BLUE** VERY SLIGHT IMPERFECTIONS AS REGARDS HOMOGENITY IN THE FORM OF ONE OR MORE OF THE FOLLOWING DEFECT GAS CAVITY, SHRINKAGE CAVITY, SLAG INCLUSION AND UNDER CUT.

IIW RADIOGRAPHIC STANDARDS FOR EVALUATION OF WELD DEFECTS.

- **GREEN** SLIGHT IMPERFECTIONS AS REGARDS
HOMOGENITY IN THE FORM OF ONE OR MORE OF THE
FOLLOWING DEFECT GAS CAVITY, SHRINKAGE CAVITY, SLAG
INCLUSION, UNDER CUT AND INCOMPLETE PENETRATION.

- **BROWN** MARKED IMPERFECTIONS AS REGARDS
HOMOGENITY IN THE FORM OF ONE OR MORE OF THE
FOLLOWING DEFECT GAS CAVITY, SHRINKAGE CAVITY, SLAG
INCLUSION, UNDER CUT, INCOMPLETE PENETRATION AND
FUSION DEFECT.

RADIOGRAPHIC STANDARDS FOR EVALUATION OF WELD DEFECTS.

- **RED** GROSS IMPERFECTIONS AS REGARDS
HOMOGENITY IN THE FORM OF ONE OR MORE OF
THE FOLLOWING DEFECT GAS CAVITY,
SHRINKAGE CAVITY, SLAG INCLUSION, UNDER
CUT, INCOMPLETE PENETRATION, FUSION DEFECT
AND CRACK

IIW BLUE STANDARD IS FOLLOWED AT ICF WITH
ACCEPTANCE CRITERIA TO ICF SPECIFICATION
NO.ICF/M&C/SPEC/010

RADIOGRAPHIC STANDARDS FOR EVALUATION OF WELD DEFECTS.

RCF is using ASTM Standards for Radiographic evaluation.

- Specified Welding defects level as per ASTM E- 390 Vol-II
 - Shrinkage /Crack of any kind are **not allowed**
 - Lack of Fusion is **not allowed**
 - Incomplete Penetration is **allowed up to level-II**
 - Burn through is **not allowed**
 - Undercut is **allowed upto level-IV**
 - Slag Inclusion is **allowed up to Level-III**
 - Porosity
 - » **Coarsed scattered Porosity is allowed upto level-II**
 - » **Fine scattered Porosity is allowed up to Level-IV**

 - » **Cluster Porosity is allowed up to Level-III**
 - » **Elongated Porosity is not allowed**

RADIOGRAPHIC STANDARDS FOR EVALUATION OF CAST DEFECTS

- Specified Casting defects level as per ASTM E- 446
 - The castings should be significantly free from harmful casting defects like :
 - » Shrinkage /Crack
 - » Sand and Slag inclusions
 - » Gas porosity or blow holes etc



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