

# Module 5 - Radiography Testing

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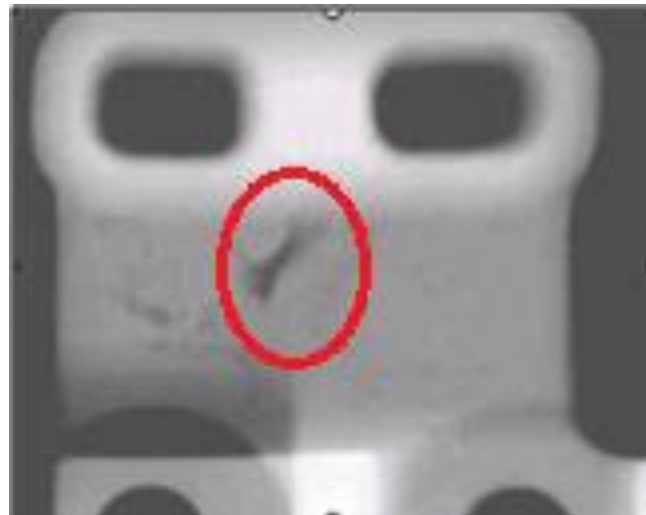
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# Radiography

- Radiography is used in a very wide range of applications including medicine, engineering, forensics, security, etc.
- In NDT, radiography is one of the most important and widely used methods.
- Radiographic testing (RT) offers a number of advantages over other NDT methods, however, one of its major disadvantages is the health risk associated with the radiation.

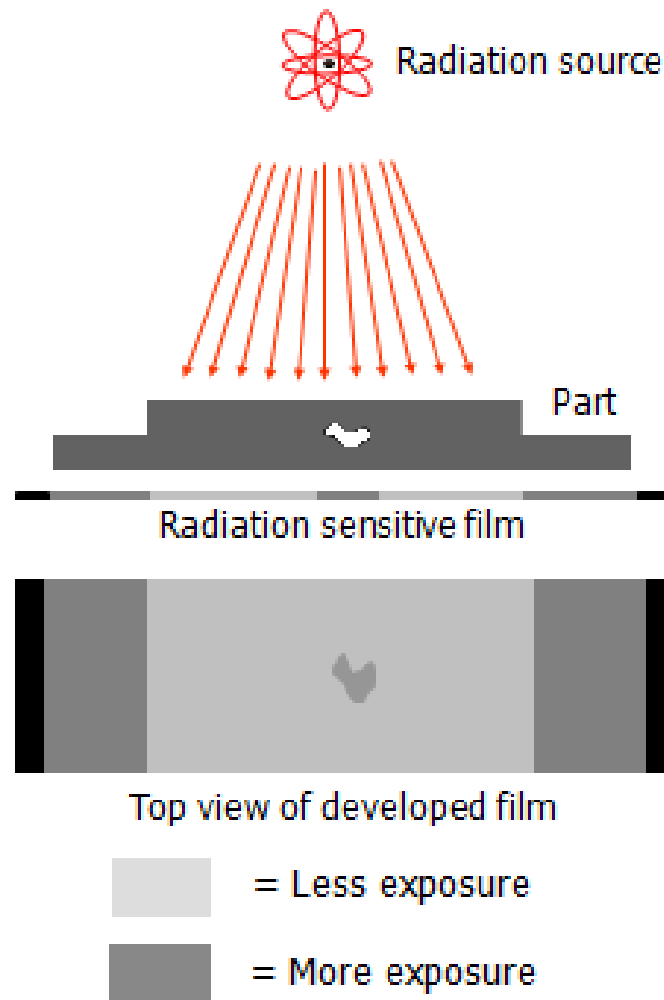
- RT is one of the most widely used NDT methods for the detection of internal defects such as porosity and voids.
- With proper orientation of the X-ray beam, planar defects can also be detected with radiography.
- It is also suitable for detecting changes in material composition, thickness measurements and locating unwanted or defective components hidden from view in an assembled part.

- In general, RT is method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials.
- The intensity of the radiation that penetrates and passes through the material is either captured by a radiation sensitive film (Film Radiography) or by a planer array of radiation sensitive sensors (Real-time Radiography).
- Film radiography is the oldest approach, yet it is still the most widely used in NDT.



# Basic Principles

- In radiographic testing, the part to be inspected is placed between the radiation source and a piece of radiation sensitive film.
- The radiation source can either be an X-ray machine or a radioactive source.
- The part will stop some of the radiation where thicker and more dense areas will stop more of the radiation.
- The radiation that passes through the part will expose the film and forms a shadowgraph of the part.
- The film darkness (density) will vary with the amount of radiation reaching the film through the test object,
- where darker areas indicate more exposure (higher radiation intensity) and lighter areas indicate less exposure (higher radiation intensity).



**The variation in the image darkness can be used to determine thickness or composition of material and would also reveal the presence of any flaws or discontinuities inside the material.**

# Advantages of RT

- Both surface and internal discontinuities can be detected.
- Significant variations in composition can be detected.
- It can be used on a variety of materials.
- Can be used for inspecting hidden areas (*direct access to surface is not required*)
- Very minimal or no part preparation is required.
- Permanent test record is obtained.
- Good portability especially for gamma-ray sources.

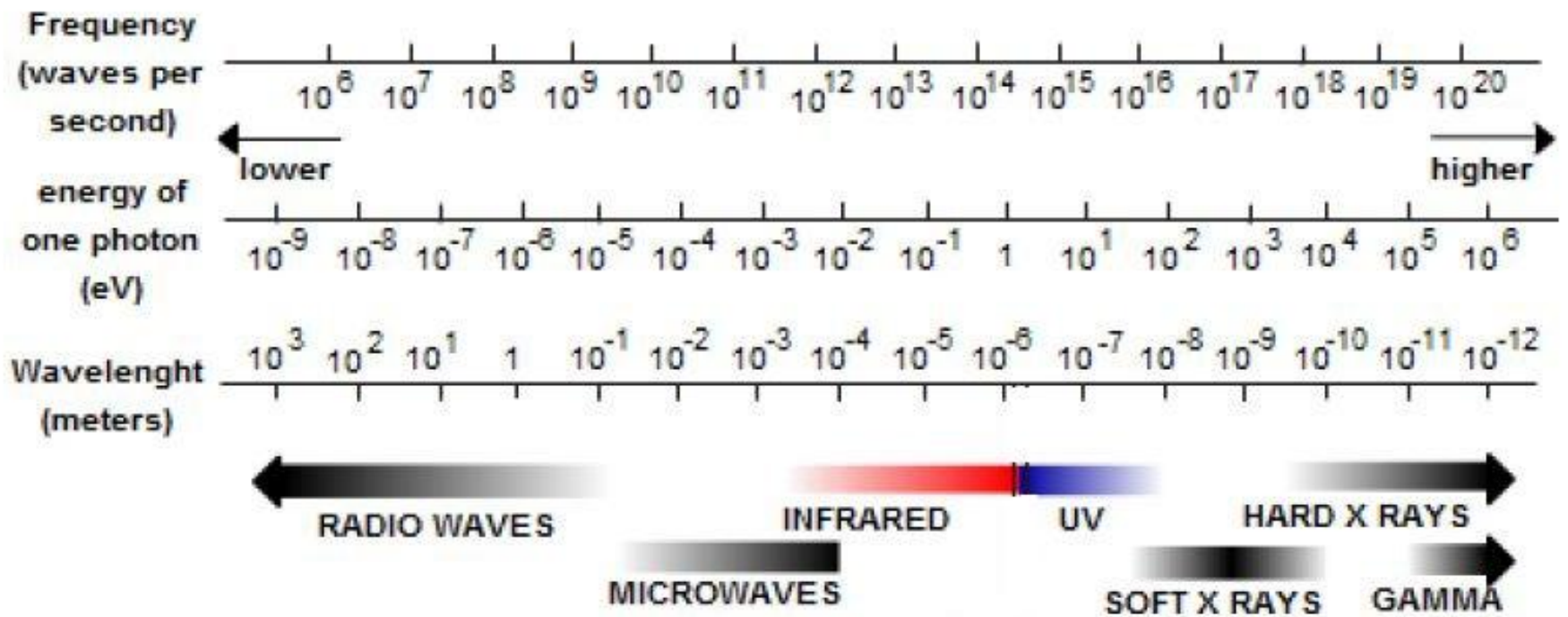
# Disadvantages

- Hazardous to operators and other nearby personnel.
- High degree of skill and experience is required for exposure and interpretation.
- The equipment is relatively expensive (*especially for x-ray sources*).
- The process is generally slow.
- Highly directional (*sensitive to flaw orientation*).
- Depth of discontinuity is not indicated.
- It requires a two-sided access to the component.



# *PHYSICS OF RADIATION*

- **Nature of Penetrating Radiation**
- Both X-rays and gamma rays are electromagnetic waves and on the electromagnetic spectrum they occupy frequency ranges that are higher than ultraviolet radiation.
- In terms of frequency, gamma rays generally have higher frequencies than X-rays.
- The major distinction between X-rays and gamma rays is the origin where X-rays are usually artificially produced using an X-ray generator and gamma radiation is the product of radioactive materials.
- Both X-rays and gamma rays are waveforms, as are light rays, microwaves, and radio waves.
- X-rays and gamma rays cannot be seen, felt, or heard. They possess no charge and no mass and, therefore, are not influenced by electrical and magnetic fields and will generally travel in straight lines.
- However, they can be diffracted (bent) in a manner similar to light.



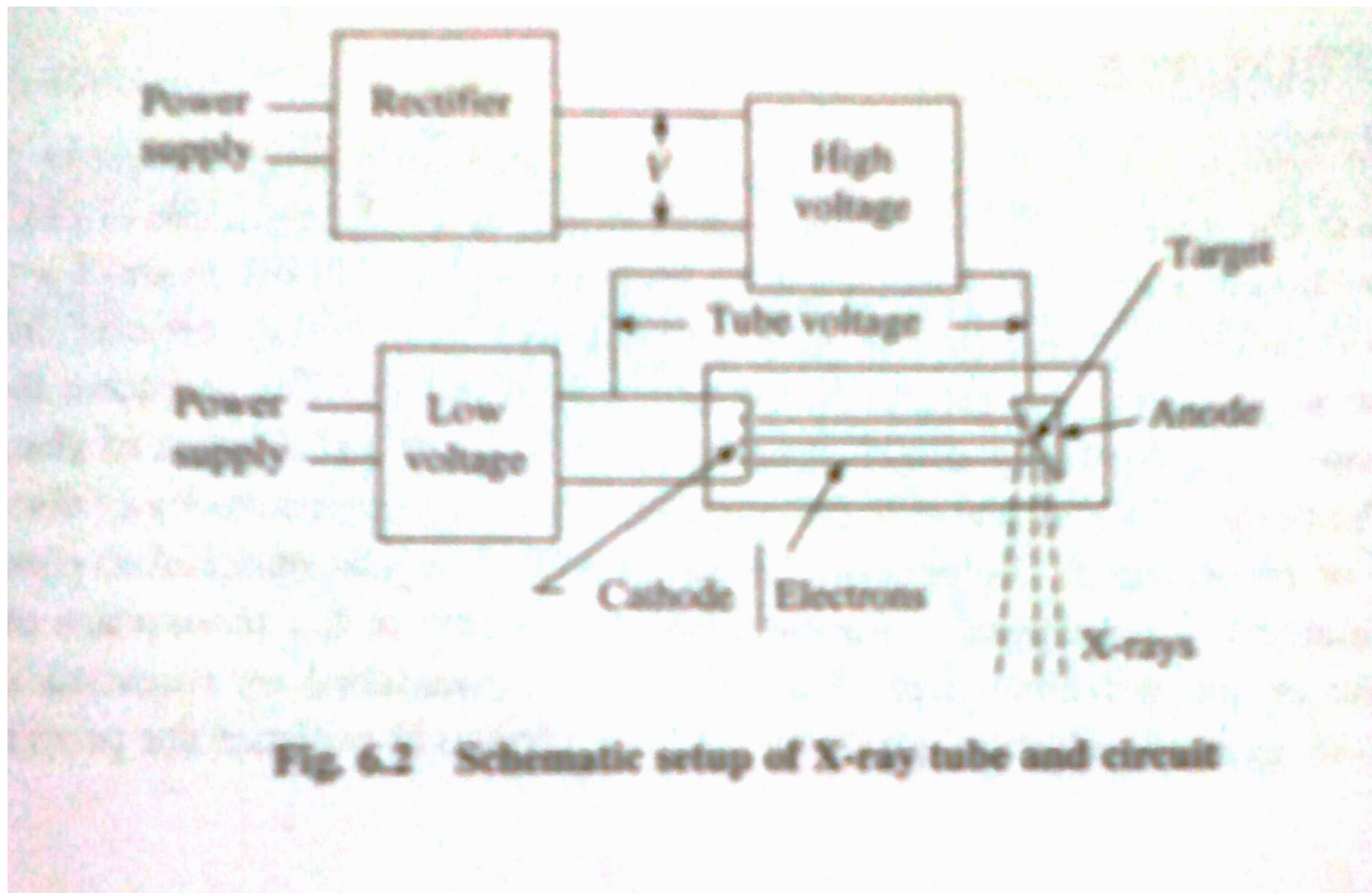
- Electromagnetic radiation acts somewhat like a particle at times in that they occur as small “packets” of energy and are referred to as “photons”.
- Each photon contains a certain amount (or bundle) of energy, and all electromagnetic radiation consists of these photons.
- The only difference between the various types of electromagnetic radiation is the amount of energy found in the photons.
- Due to the short wavelength of X-rays and gamma rays, they have more energy to pass through matter than do the other forms of energy in the electromagnetic spectrum.
- As they pass through matter, they are scattered and absorbed and the degree of penetration depends on the kind of matter and the energy of the rays.

# Properties of X-Rays and Gamma Rays

- They are not detected by human senses (cannot be seen, heard, felt, etc.).
- They travel in straight lines at the speed of light.
- Their paths cannot be changed by electrical or magnetic fields.
- They can be diffracted, refracted to a small degree at interfaces between two different materials, and in some cases be reflected.
- Their degree of penetration depends on their energy and the matter they are traveling through.
- They have enough energy to ionize matter and can damage or destroy living cells.

# Electromagnetic Radiation sources

- **X ray source**
- In the widely used conventional X radiography, the source of radiation is an X-ray tube.
- It consists of a glass tube under vacuum, enclosing a positive electrode or 'anode' and a negative electrode or 'cathode'.
- The cathode comprises a filament, which when brought to incandescence by a current of a few amperes, emits electrons.
- Under the effect of electrical tension set up between the anode and the cathode, these electrons are attracted to the anode.



**Fig. 6.2 Schematic setup of X-ray tube and circuit**

- The stream of electrons is concentrated in a beam by a cylinder or a focusing cup.
- The anti-cathode is a slip of metal with high melting point recessed in to the anode, where it is struck by the beam of electrons.
- It is by impinging on the anti-cathode that fast moving electrons give rise to X-rays.

- The development of electronics has led to the availability of constant potential units which give stable operating conditions.
- The replacement of glass tubes by metal ceramic ones has led to an extended tube life.
- X-ray machines are characterized by the operating voltage and current which determine the penetrability and intensity of radiation produced.
- Modern X-ray generators are available up to 450 kV and 50 mA.
- Highly automated self propelled X-ray mini-crawlers which travel within pipelines are used to take radiographs of pipelines and welds from inside.



- **The area of the anti-cathode which is struck by the electron flux is called the ‘focal spot’ or TARGET.**
- It is essential that this area should be sufficiently large, in order to avoid local heating which may damage the anti-cathode and to allow rapid dissipation of heat.
- The projection of the focal spot on a surface perpendicular to the axis of the beam of X-rays is termed as the ‘optical focus’ or ‘focus’.
- This focus has to be as small as possible in order to achieve maximum sharpness in the radiographic image.

# Production of X-rays

- X-rays are produced when fast moving electrons are suddenly brought to rest by colliding with matter.
- Electrons may also lose energy by ionization and excitation of the target atoms.
- The accelerated electrons lose their kinetic energy (KE) very rapidly at the surface of the metal plate, and energy conversion occurs.

- Conversion in 3 different ways:
- **1.** A very small fraction (< 1 %) is converted into X radiation.
- The conversion factor  $f$  can be estimated using an empirical relation  $f = 1.1 \times 10^{-9} ZV$
- $Z$  = atomic number of the target,  $V$  = energy of electron in volts.
- **2.** Approximately 99% of energy of electrons is converted into heat by increasing the thermal vibration of the atoms of the target, the temperature of which may rise considerably.
- **3.** Some of the electrons have sufficient energy to eject orbital electrons from the atoms of the target material that are ionized.
- The secondary electrons produced in this way may escape from the surface of the target and subsequently be recaptured by it producing further heat or secondary radiation.

- The two important distinguishing features of a beam of X rays are its intensity and quality.
- The first term refers to how much radiation (quantity).
- The second term refers to the kind of radiation (how penetrating it is).

# High energy X-ray source

- Inspection of thicker sections is carried out using high energy X-rays ( energy value 1 MeV or more).
- Using high energy X-rays, possibilities of large distance to thickness ratios with correspondingly low geometrical distortion, short exposure times and high production rate can be achieved.
- Also, small focal spot size and reduced amount of high angle scattered X-rays reaching the film result in radiographs with good contrast, excellent sensitivity and good resolution.
- A number of machines are available: synchrotron, betatron, Van De Graff type electrostatic generators etc

# Gamma Radiation

- *Radioactivity*, is the process by which a nucleus of an unstable atom loses energy by emitting ionizing radiation.
- Gamma radiation is one of the three types of natural radioactivity.
- The other two types of natural radioactivity are alpha and beta radiation, which are in the form of particles.
- Gamma rays are electromagnetic radiation just like X-rays.
- Gamma rays are the most energetic form of electromagnetic radiation.

- Gamma radiation is the product of radioactive atoms.
- Depending upon the ratio of neutrons to protons within its nucleus, an isotope of a particular element may be stable or unstable.
- When the binding energy is not strong enough to hold the nucleus of an atom together, the atom is said to be unstable.
- Atoms with unstable nuclei are constantly changing as a result of the imbalance of energy within the nucleus.
- Over time, the nuclei of unstable isotopes spontaneously disintegrate, or transform, in a process known as *“radioactive decay”* and such material is called *“radioactive material”*.

- Gamma-rays
- A nucleus which is in an excited state (unstable nucleus) may emit one or more photons of discrete energies.
- The emission of gamma rays does not alter the number of protons or neutrons in the nucleus but instead has the effect of moving the nucleus from a higher to a lower energy state (unstable to stable).
- Gamma ray emission frequently follows beta decay, alpha decay, and other nuclear decay processes.



# Basic terms

- Isotopes
- The number of nucleons (both protons and neutrons) in the nucleus is the atoms mass number, and each **isotope** of a given element has a different mass number.
- For example, carbon-12, carbon-13 and carbon-14 are three **isotopes** of the element carbon with mass numbers 12, 13 and 14 respectively.
- Half life
- Half-life is the amount of time required for a quantity to fall to half its value as measured at the beginning of the time period.
- It is the time required, for half of the unstable, radioactive atoms in a sample to undergo radioactive decay.

# Gamma ray sources

- Gamma rays are electromagnetic radiation emitted from an unstable nucleus.
- X-ray machines emit a broad band of wavelengths, but Gamma ray sources emit one or a few discrete wavelengths.
- Radiography with gamma rays has the advantages of simplicity of the apparatus, compactness of radiation source and independence from outside power.
- This facilitates examination of pipes, pressure vessels and other assemblies in which the access to interior is difficult.
- Each isotope with unstable nucleus will have characteristic nuclear energy levels and intensities for the emitted radiation.
- The gamma ray energy levels remain constant for a particular isotope but the intensity decays with time as indicated by the half life.

- A variety of radioisotopes are produced in a nuclear reactor but a few have been utilized for the purposes of radiography.
- Other isotopes are unsuitable for a variety of reasons such as shorter half life, low intensity and high cost of production.
- The 4 most popular radiographic sources are Cobalt 60 (Co-60), Iridium 192 (Ir-192), Caesium 137 (Cs-137) and Thulium 170 (Th-170).

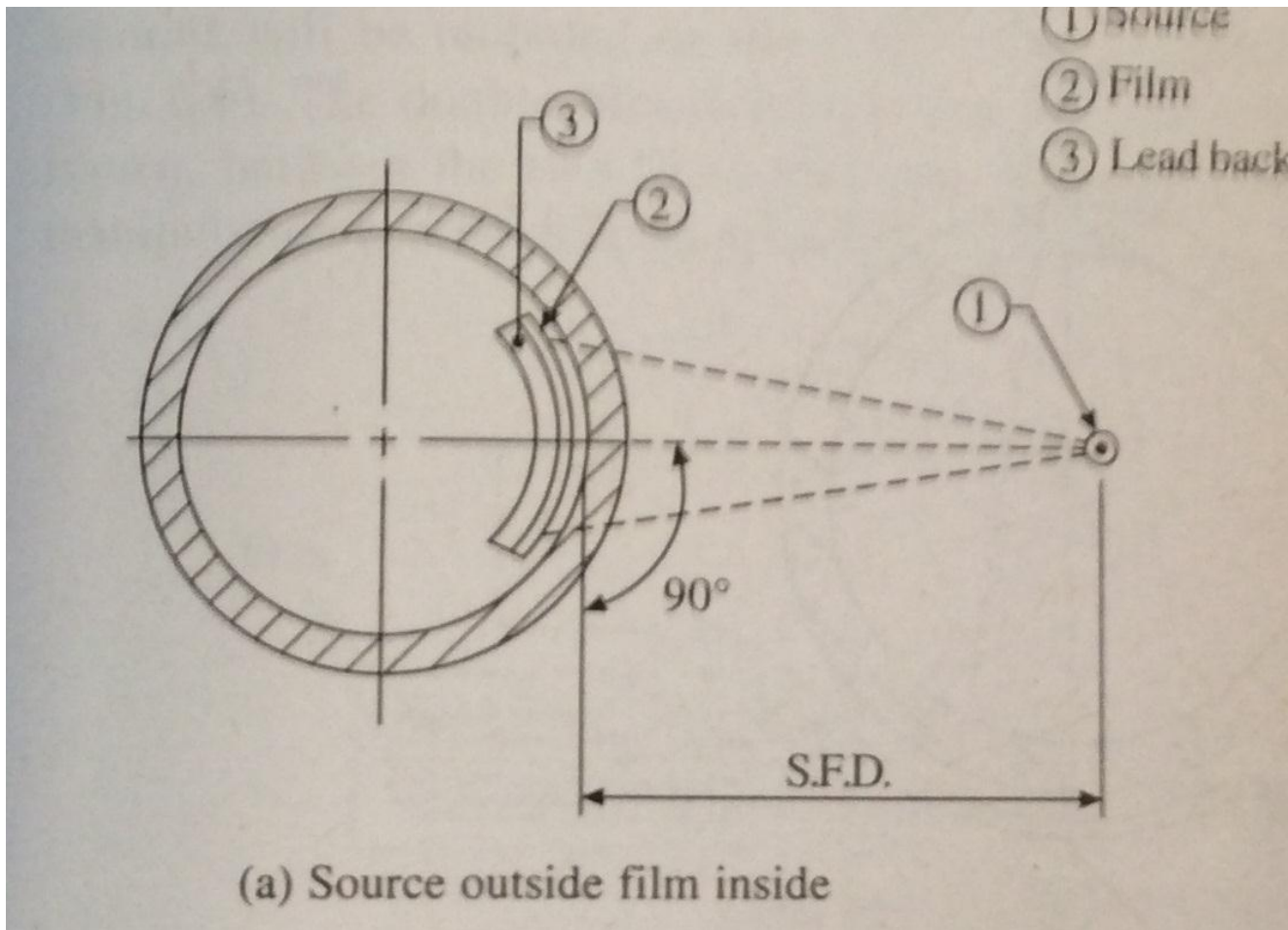
- Manmade radioactive sources are produced by introducing an extra neutron to atoms of the source material.
- As the material gets rid of the neutron, energy is released in the form of gamma rays.
- Two of the most common industrial gamma-ray sources for industrial radiography are Iridium-192 and Cobalt-60.
- In comparison to an X-ray generator, Cobalt-60 produces energies comparable to a *1.25 MV X-ray system and Iridium-192 to a 460 kV X-ray system.*
- *These high energies make it possible to penetrate thick materials with a relatively short exposure time.*

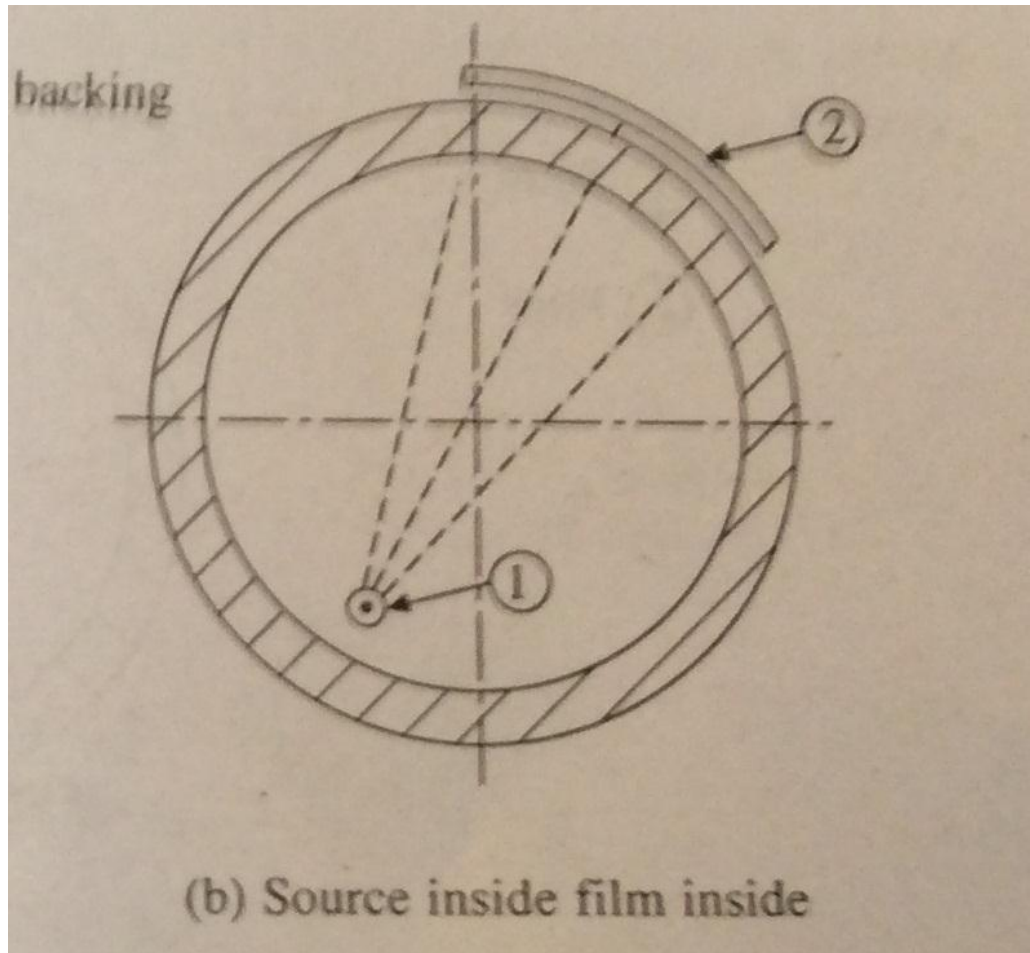
# Inspection techniques

- With the various techniques available, the choice of appropriate one is made on the basis of geometry, size, sensitivity requirements, in-situ space availability etc.
- The techniques used for various engg components for radiographic inspection are:
  1. Single wall single image technique
  2. Double wall penetration technique
    - a. Double wall single image
    - b. Double wall double image
    - c. Double wall superimposing image

# Single wall single image technique (SWSI)

- Used when both the sides of the specimen are accessible.
- The source is kept outside and the film inside or vice versa and the weld is exposed part by part (a smaller length of weld).
- This is used for plates, cylinders, shells and large diameter pipes.

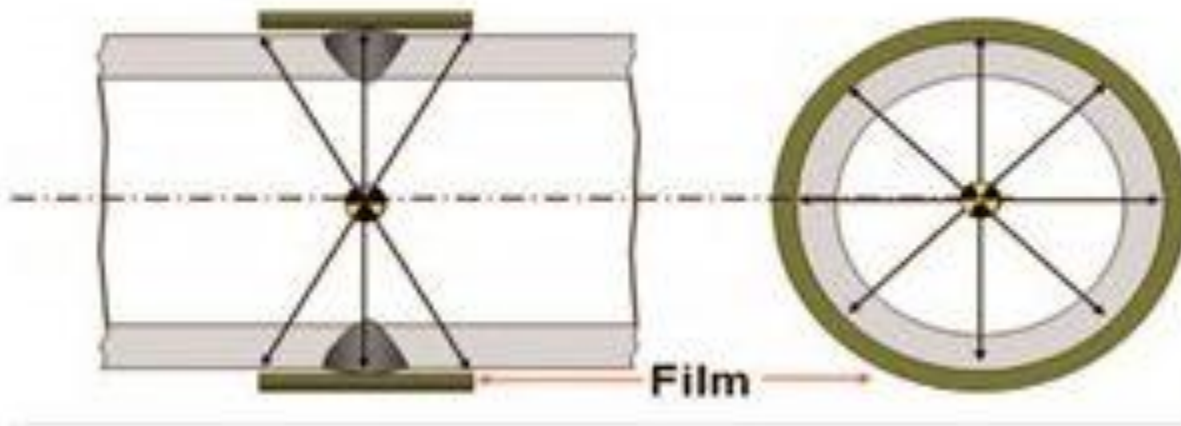






# Panoramic technique

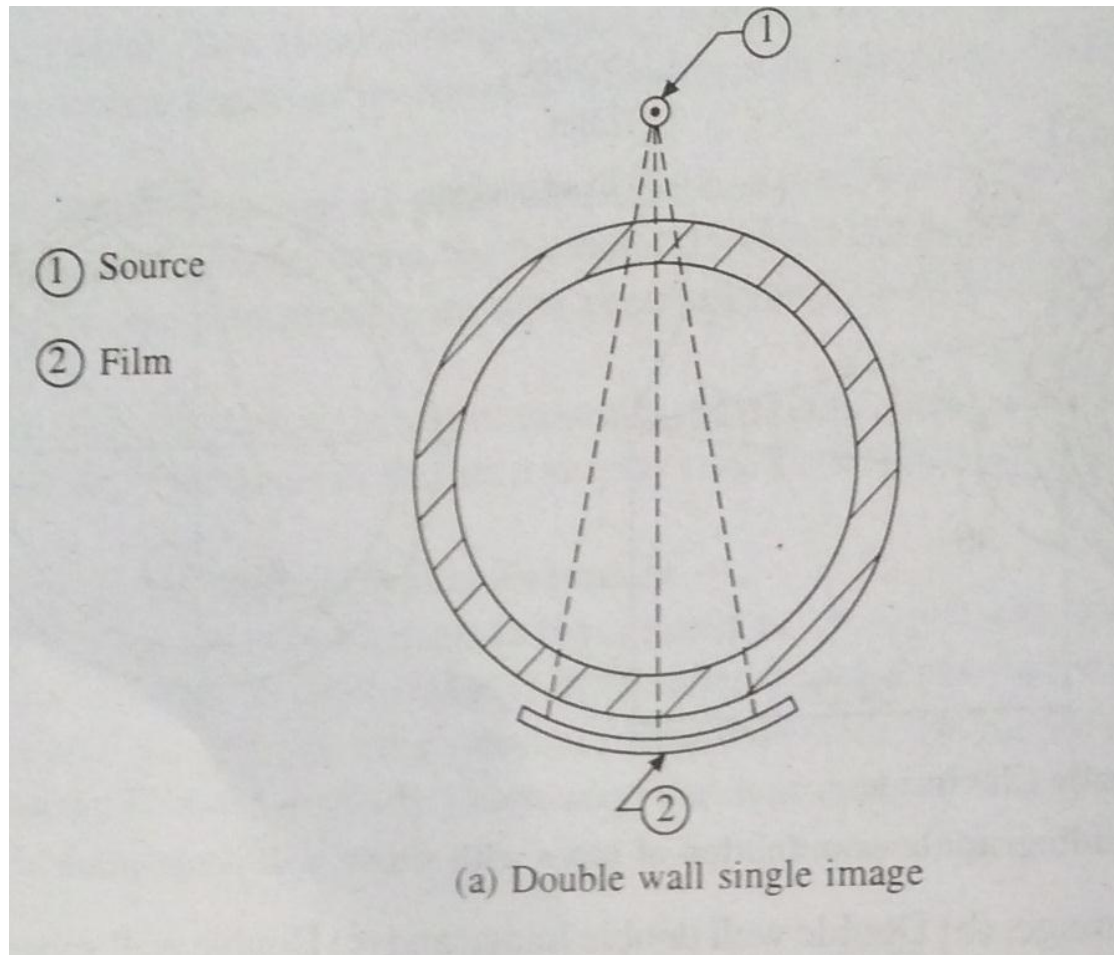
- The radiation source is kept in the centre of the pipe and the film is fixed around the weld on the outer surface of the pipe.
- The total circumferential weld length is exposed at a time.
- Reduces the examination time considerably.
- It can be effectively employed only when the source to film distance is sufficient enough to ensure the proper sensitivity.



# Double wall penetration technique

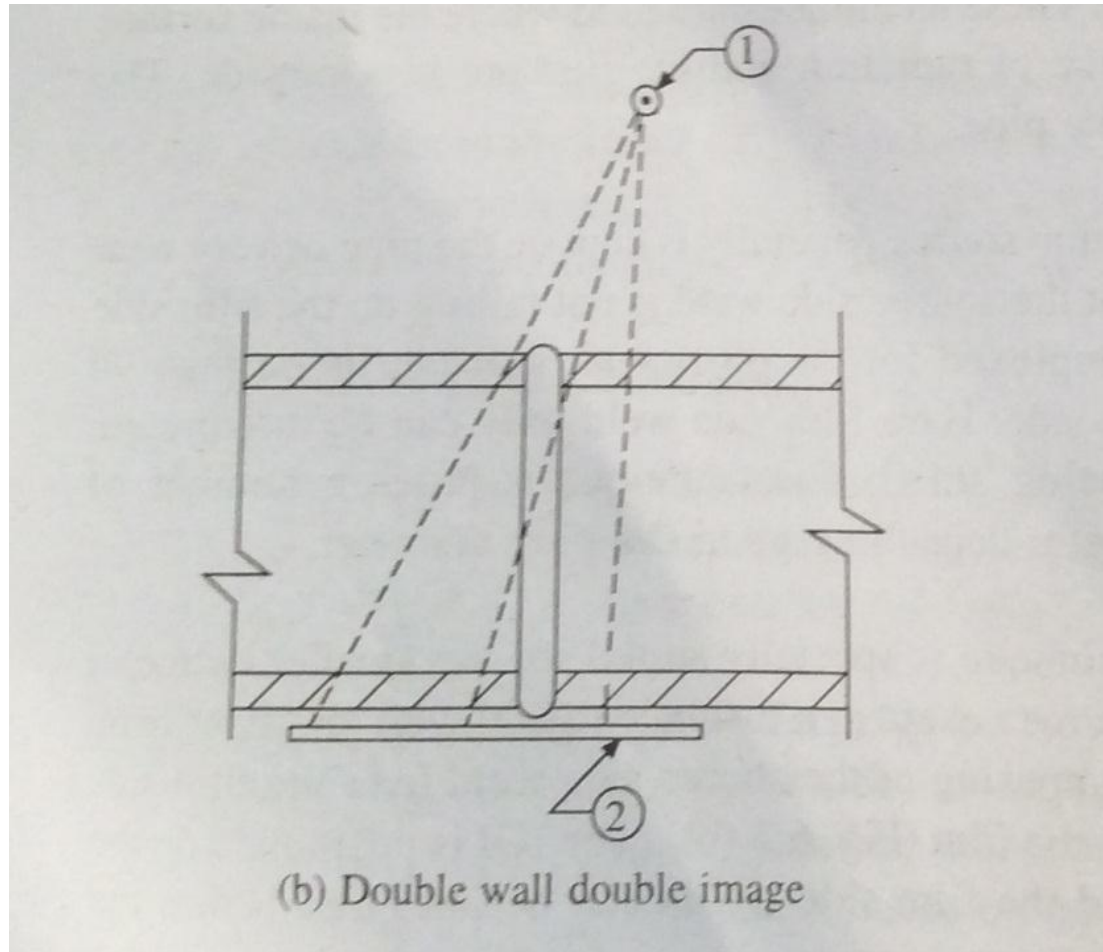
- Used where the inside surface of the pipe is not accessible.
- The source of radiation and the film are kept outside.
- The radiation penetrates both the walls of the pipe.
- This can be effectively adopted in 3 different methods.
  1. Double wall single image (DWSI)
  2. Double wall double image (DWDI)
  3. Double wall superimposing image

# Double wall single image (DWSI)



- The radiation source is kept on the pipe or very near to the OD and just near the weld.
- Used for pipes with diameter more than 90 mm OD.
- The image quality indicator (IQI) is placed on the film side.
- Here film side weld only can be interpreted.
- As the interpretable weld length is small, it requires a number of exposures to cover the entire weld length, depending upon the pipe diameter.

# Double wall double image (DWDI)

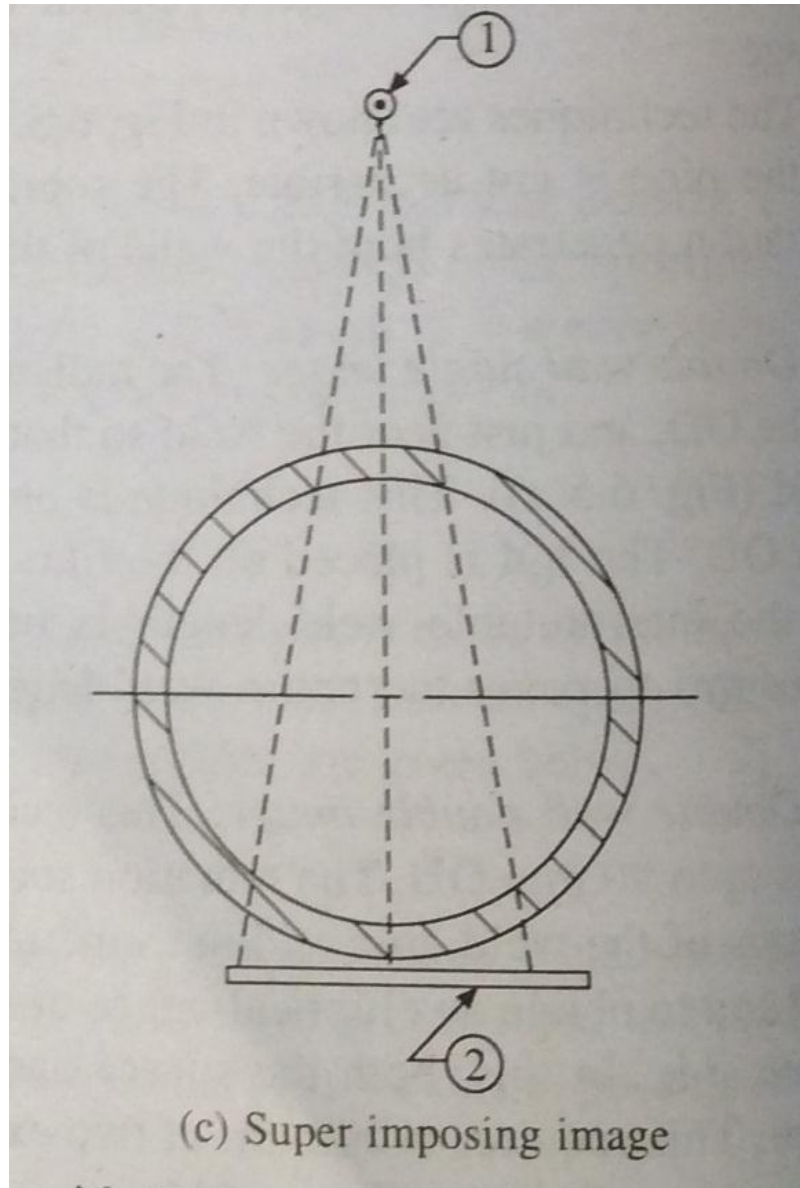


- Specially suited for small diameter pipes up to 90 mm OD.
- The radiation source is kept at a distance SFD (Source-to-Film Distance) with an offset from the axis of the weld,
- to avoid the super imposing of the source side weld over the film side weld and to obtain an elliptical image on the film.
- Here both the source and film side welds can be interpreted from the image.
- Requires min. of two exposures, perpendicular to each other, to cover the entire circumference.

# Superimposing technique

- Used when the required offset to obtain double image could not be possible due to site restrictions for the pipes with dia : 90mmOD.
- The source is kept at a distance without offset, thereby the source side weld is superimposed on the film side weld on the film.
- Requires minimum of 3 exposures each at 120° apart, to cover the entire length of the weld.

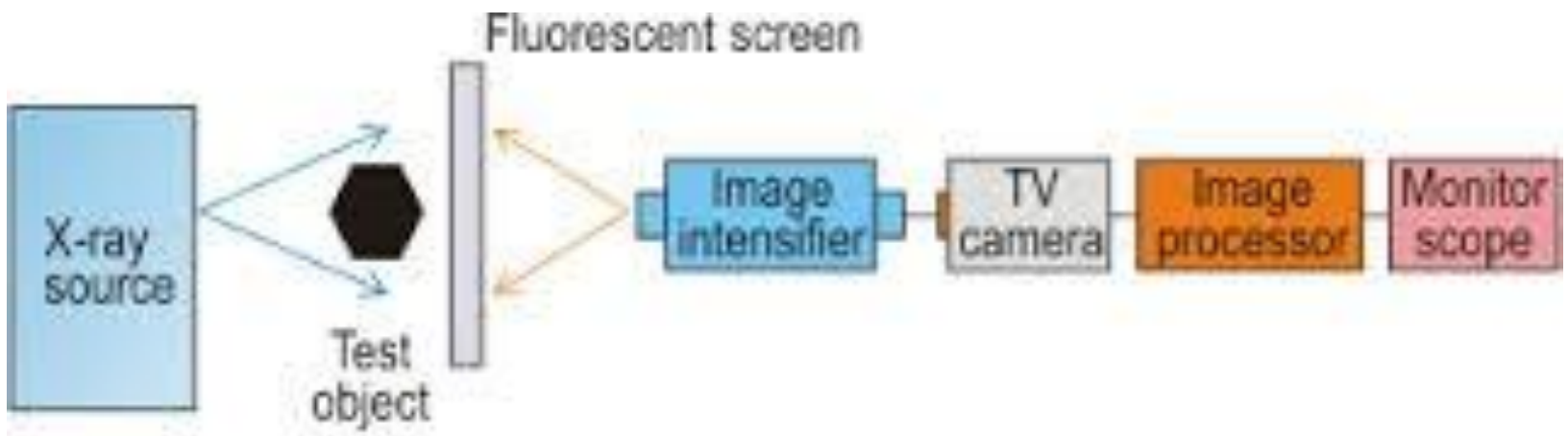




# Real time radiography

- Uses X or gamma radiation to produce a visible volumetric image of an object.
- In Film radiography, the image is viewed in a static mode; in Real time radiography, the image is interpreted at the same time as the radiation passes through the object (Dynamic mode).
- A positive image is normally presented in Real time radiography, whereas the X-ray film gives a negative image.

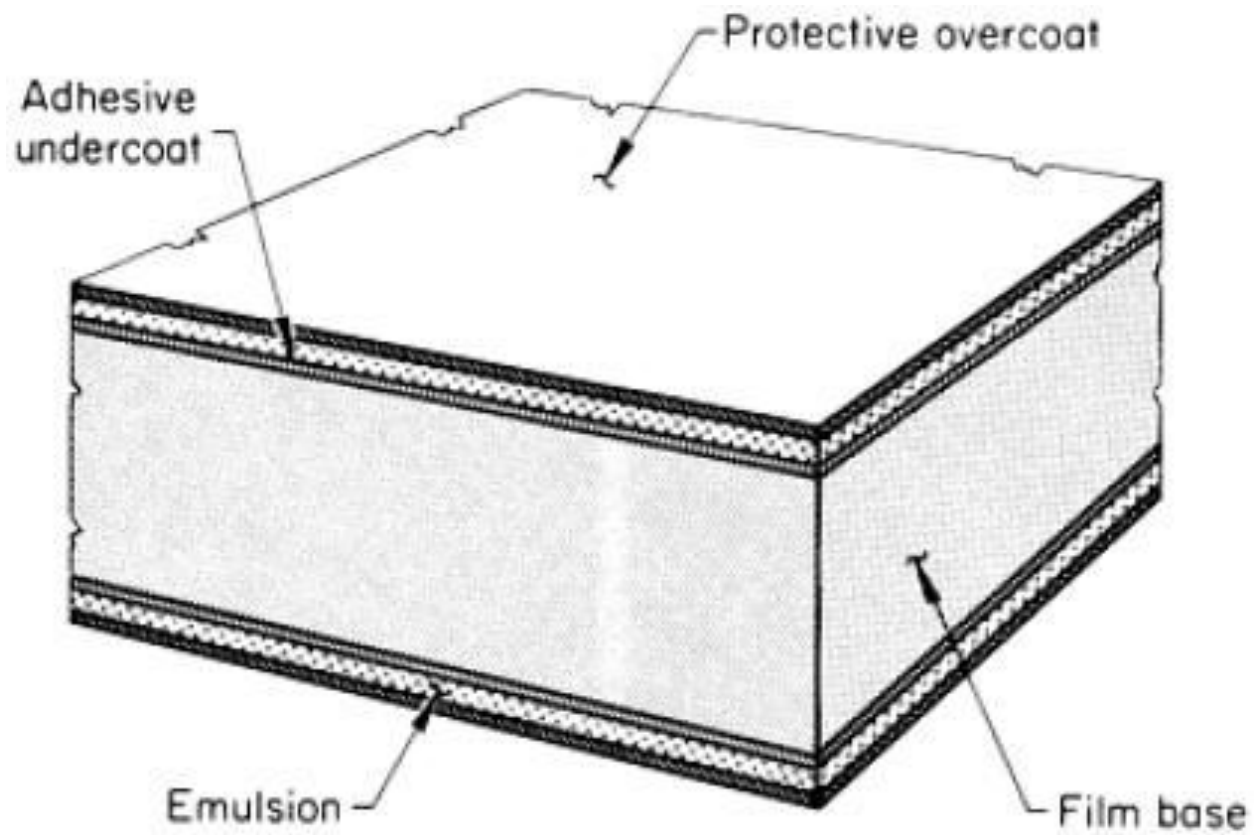
- Basic equipment consists of a source of radiation, a fluorescent screen, mirrors and a viewing port.
- Object is placed between the source and the screen.
- The fluorescent screen converts the transmitted radiation to visible light.
- A specially coated mirror then reflects the visible image to a viewing port.
- As low light levels are produced during conventional fluoroscopy, an intensifier is used to provide brightness.



- Real time radiography has the advantages of high speed and low cost of inspection.
- Real-time radiographic concept can be applied in the case of microfocal radiography. (focal spot = 100  $\mu\text{m}$ )
- In Real-time microfocal radiography the zooming is done by dynamically positioning the object with the manipulators between X-ray tube and image receptor.
- Real-time radiography can be applied to the inspection of laser welds or electron beam welds in thin pipes having thickness 1mm and porosities in the range of 0.025mm – 0.1mm can be detected in 1 second.

# Films used in industrial radiography

- They are similar to photographic film in that there is a central carrier called film base that is made of thin sheet of polyester type material.
- This is normally transparent and serves only as the carrier for the chemically reactive material that forms the emulsion.
- Emulsion consisting of a silver halide recording medium with a binder (gelatin) is applied to both sides of the base.
- The emulsion is usually coated on both sides of a flexible, transparent, blue-tinted base in layers about 0.012 mm thick.
- The typical total thickness of the X-ray film is approximately 0.23 mm.



- Though films are made to be sensitive for X-ray or gamma-ray, yet they are also sensitive to visible light.
- When X-rays, gamma-rays, or light strike the film, some of the halogen atoms are liberated from the silver halide crystal and thus leaving the silver atoms alone.
- This change is of such a small nature that it cannot be detected by ordinary physical methods and is called a “latent (hidden) image”.
- When the film is exposed to a chemical solution (developer) the reaction results in the formation of black, metallic silver.



- The film speed is another important film parameter.
- A film whose grains would begin reacting to the exposure considerably sooner than other films – High speed film.
- For a constant intensity, the grains of a high speed film would produce the required density before the grains of slow speed film.
- Grain size in a film affects quality and time of exposure.
- Faster speed films have larger grains and slow films have extra-fine or fine grains, and give better quality even though the exposure time is longer.

# Speed of film

- Speed is defined as the density recorded on the film resulting from a given radiation input.
- It is measured in terms of inverse of exposure required to produce a radiograph of a particular density, under specified conditions.
- A film requiring less exposure is called faster.

# ***Film Selection***

- Selecting the proper film and developing the optimal radiographic technique for a particular component depends on a number of different factors;
  1. Composition, shape, and size of the part being examined and, in some cases, its weight and location.
  2. Type of radiation used, whether X-rays from an X-ray generator or gamma rays from a radioactive source.
  3. Kilovoltage available with the X-ray equipment or the intensity of the gamma radiation.
  4. Relative importance of high radiographic detail or quick and economical results.

# *Film Packaging*

- Radiographic film can be purchased in a number of different packaging options and they are available in a variety of sizes.
- The most basic form is as individual sheets in a box. In preparation for use, each sheet must be loaded into a cassette or film holder in a darkroom to protect it from exposure to light.

- Industrial X-ray films are also available in a form in which each sheet is enclosed in a light-tight envelope.
- The film can be exposed from either side without removing it from the protective packaging.
- A rip strip makes it easy to remove the film in the darkroom for processing.

- Packaged film is also available in the form of rolls where that allows the radiographer to cut the film to any length.
- The ends of the packaging are sealed with electrical tape in the darkroom.
- In applications such as the radiography of circumferential welds and the examination of long joints on an aircraft fuselage, long lengths of film offer great economic advantage.

# ***Film Handling***

- X-ray film should always be handled carefully to avoid physical strains, such as pressure, creasing, buckling, friction, etc.
- Whenever films are loaded in semi-flexible holders and external clamping devices are used, care should be taken to make sure pressure is uniform.
- Marks resulting from contact with fingers that are moist or contaminated with processing chemicals, as well as crimp marks, are avoided if large films are always grasped by the edges and allowed to hang free.
- Use of envelope-packed films avoids many of these problems until the envelope is opened for processing.

# Intensifying screens

- The radiographic image is formed by only approximately 1 % of the amount of radiation energy exposed at the film.
- The rest passes through the film and is consequently not used.
- To utilize more of the available radiation energy, the film is sandwiched between two intensifying screens.
- The screens help to cut down the exposure time by utilizing more effectively the radiations reaching the film.
- The intensification effect is primarily due to the liberation of photoelectrons from the screen.
- Different types of materials are being used for this purpose.
  - Lead screens
  - Steel and copper screens
  - Fluorescent screens
  - Salt screens
  - Fluorometallic screens



- Lead screens
- Under the impact of X-rays and gamma-rays, lead screens emit electrons to which the film is sensitive.
- In industrial radiography this effect is made use of: the film is placed between two layers of lead to achieve the intensifying effect and intensity improvement of approximately factor 4 can be realized.
- This method of intensification is used within the energy range of 80 keV to 420 keV, and applies equally to X-ray or gamma-radiation, such as produced by Iridium192.

- Intensifying screens are made up of two homogeneous sheets of lead foil (stuck on to a thin base such as a sheet of paper or cardboard) between which the film is placed: the so called front and back screens.
- The thickness of the front screen (source side) must match the hardness of the radiation being used, so that it will pass the primary radiation while stopping as much as possible of the secondary radiation (which has a longer wavelength and is consequently less penetrating).
- The surface of lead screens is polished to allow as close a contact as possible with the surface of the film.
- Flaws such as scratches or cracks on the surface of the metal will be visible in the radiograph and must, therefore, be avoided.

- Steel and copper screens
- For high-energy radiation, lead is not the best material for intensifying screens.
- With Cobalt60 gamma-rays, copper or steel have been shown to produce better quality radiographs than lead screens.
- With megavoltage X-rays in the energy range 5-8 MeV (linac) thick copper screens produce better radiographs than lead screens of any thickness.

- Fluorescent screens
- The term fluorescence (often mistaken for phosphorescence) is used to indicate the characteristic of a substance to instantly emit light under the influence of electromagnetic radiation.
- The moment radiation stops, so does the lighting effect.
- This phenomenon is made good use of in film based radiography.
- Certain substances emit so much light when subjected to ionising radiation, that they have considerably more effect on the light sensitive film than the direct ionising radiation itself..

- Salt screens
- These are fluorescent screens consisting of a thin, flexible base coated with a fluorescent layer made up from micro-crystals of a suitable metallic salt (rare earth; usually calcium tungstate) which fluoresce when subjected to radiation.
- The radiation makes the screen light up.
- The light intensity is in direct proportion to the radiation intensity.
- With these screens a very high intensification factor of 50 can be achieved, which means a significant reduction in exposure time.
- The image quality, however, is poor because of increased image unsharpness.
- Fluorescent screens are only used in industrial radiography when a drastic reduction of exposure time, in combination with the detection of large defects, is required.

- Fluorometallic screens
- Apart from fluorescent and lead intensifying screens, there are fluorometallic screens which to a certain extent combine the advantages of both.
- These screens are provided with a lead foil between the film base and the fluorescent layer.
- This type of screen is intended to be used in combination with so-called RCF-film (Rapid Cycle Film).
- The degree of intensification achieved largely depends on the spectral sensitivity of the X-ray film for the light emitted by the screens.

# Types of Films

- (a) On the basis of photosensitive emulsion layer
  - i) Single coated
  - ii) Double coated
  
- (b) On the basis of intensifying screens
  - i) Screen films
  - ii) Non-screen films
  
- (c) On the basis of type of emulsion coating
  - i) Blue light sensitive films
  - ii) Green light sensitive films (Orthochromatic)
  - iii) Red light sensitive films (Panchromatic)
  
- (d) On the basis of film speed
  - i) Standard speed films
  - ii) Fast speed films
  - iii) Ultra fast films

# Types of films

- Can be divided into 3 groups on the basis of radiography considerations.
  - i. Films for use with salt screens, also known as salt screen films.
  - ii. Films for use with metal screens or without screens also called direct films. This group covers a large range of film speeds.
  - iii. Films used for special purposes, such as single emulsion films.



- i) Salt screen films
- These are used with salt screens.
- Salt screens are fluorescent screens consisting of a thin, flexible base coated with a fluorescent layer made up from micro-crystals of a suitable metallic salt (usually calcium tungstate) which fluoresce when subjected to radiation.
- The use of salt screens causes loss of definition and hence these films should be used where their disadvantages are clearly understood and tolerable.
- For about 90% of the medical work, salt screen films are used.

- ii) Direct films
- Generally used with metal screens.
- This group covers industrial films and some of the medical films.
- The contrast of industrial film increases as density increase, whereas that of a medical film readily react as a maximum with increasing density.
- Industrial films have coating weights, which are usually between 2-2.5 times those of normal screen type medical films.

- iii) Special purpose films
- These find less frequent use in radiography and are discussed below.
- a) Fluorographic films
- These films are used for photographing a fluorescent screen on which X-ray image has been projected.
- These films are usually sensitive to blue or blue-green glow emitted by the screen in use.
- They differ from normal X-ray films in that they are coated on one side only.

- b) X-ray paper
- Instant cycle X-ray papers are the latest addition to the family of X-ray films.
- When used in instant cycle processor units, these papers develop to completion within seconds by the developing agents contained in the emulsion.
- Good for fast radiographic examinations.
- This paper is cheap compared to X-ray films and processing cost is very low.

# Film Processing

- As mentioned previously, radiographic film consists of a transparent, blue-tinted base coated on both sides with an emulsion.
- The emulsion consists of gelatin containing microscopic, radiation sensitive silver halide crystals, such as silver bromide and silver chloride.
- When X-rays, gamma rays or light rays strike the crystals or grains, some of the Br<sup>-</sup> ions are liberated leaving the Ag<sup>+</sup> ions.
- In this condition, the radiograph is said to contain a latent (hidden) image because the change in the grains is virtually undetectable, but the exposed grains are now more sensitive to reaction with the developer.

- When the film is processed, it is exposed to several different chemical solutions for controlled periods of time.
- Film processing basically involves the following five steps:
- 1.Development: The developing agent gives up electrons to convert the silver halide grains to metallic silver.
- Grains that have been exposed to the radiation develop more rapidly, but given enough time the developer will convert all the silver ions into silver metal.
- Proper temperature control is needed to convert exposed grains to pure silver while keeping unexposed grains as silver halide crystals.

- 2. Stopping the development: The stop bath simply stops the development process by diluting and washing the developer away with water.
- 3. Fixing: Unexposed silver halide crystals are removed by the fixing bath. The fixer dissolves only silver halide crystals, leaving the silver metal behind.
- 4. Washing: The film is washed with water to remove all the processing chemicals.
- 5. Drying: The film is dried for viewing.
  
- Film processing is a strict science governed by rigid rules of chemical concentration, temperature, time, and physical movement.
- Whether processing is done by hand or automatically by machine, excellent radiographs require a high degree of consistency and quality control.

# Viewing Radiographs

- After the film processing, radiographs are viewed using a light-box (or they can be digitized and viewed on a high resolution monitor) in order to be interpreted.
- In addition to providing diffused, adjustable white illumination of uniform intensity, specialized industrial radiography light-boxes include magnifying and masking aids.
- When handling the radiographs, thin cotton gloves should be worn to prevent fingerprints on the radiographs.



# Interpretation and Evaluation of Test results

- The common term for film interpretation is film viewing.
- Film viewing in fact means the evaluation of the image quality of a radiograph for compliance with the code requirements and the interpretation of details of any possible defect visible on the film.
- For this purpose, the film is placed in front of an illuminated screen of appropriate brightness/luminance.
- The edges of the film and areas of low density need to be masked to avoid glare.
- The following conditions are important for good film interpretation:
  - brightness of the illuminated screen (luminance)
  - density of the radiograph
  - diffusion and evenness of the illuminated screen
  - ambient light in the viewing room
  - film viewer's eye-sight
- Poor viewing conditions may cause important defect information on a radiograph to go unseen.

- The light of the viewing box must be diffusive and preferably white.
- Radiographs should be viewed in a darkened room, although total darkness is not necessary.
- Care must be taken that as little light as possible is reflected off the film surface towards the film viewer.
- If the film viewer enters a viewing room from full daylight, some time must be allowed for the eyes to adapt to the dark.

- An yearly eye-test for general visual acuity is required while especially sight at close range needs to be checked.
- The film viewer must be able to read a Jaeger number 1 letter at 300 mm distance with one eye, with or without corrective aids.
- The trained eye is capable of discerning an abrupt density change/step of 1 %.
- While interpreting, a magnifying glass of power 3 to 4 can be advantageous.

- The film-interpreter
- Apart from the requirements regarding “viewing conditions” and “viewing equipment” the film-interpreter (film viewer) shall have thorough knowledge of the manufacturing process of the object being examined and of any defects it may contain.
- The type of defects that may occur in castings, obviously, differs from those in welded constructions.
- Different welding processes have their own characteristic defects which the film interpreter must know to be able to interpret the radiograph.

- To become a qualified NDT operator, various training courses, course materials and leaflets specifying the requirements they need to comply with, exist.
- The European NDT industry conforms to the qualification standards of the American ASNT organization.
- So far, a training program for film-interpreter has not been established in similar fashion.
- Textbooks for example are not uniform.
- Sometimes, the IIW-weld defect reference collection is used, beside which the instructor usually has his own collection of typical examples, supplemented with process-specific radiographs.
- ASTM has a reference set of defects in castings available.

# Radiograph Interpretation - Welds

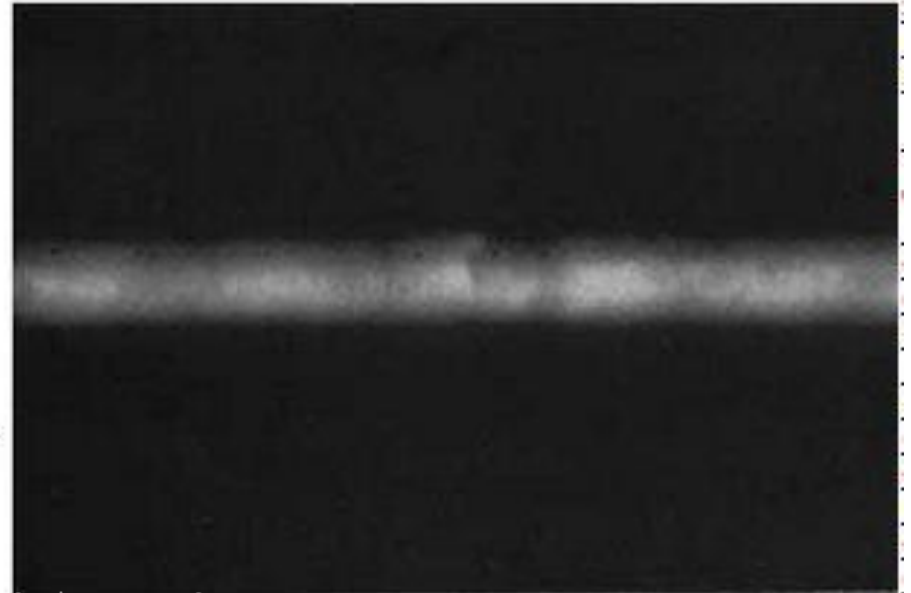
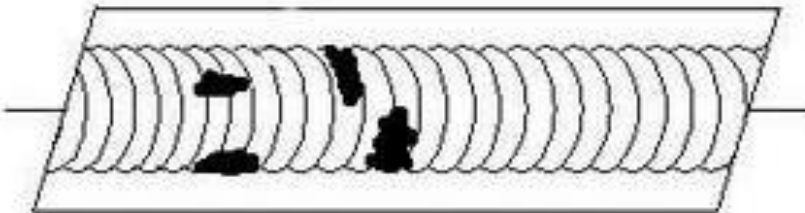
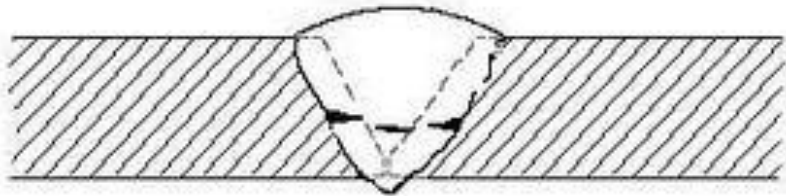
- In addition to producing high quality radiographs, the radiographer must also be skilled in radiographic interpretation.
- Interpretation of radiographs takes place in three basic steps: (1) detection, (2) interpretation, and (3) evaluation.
- All of these steps make use of the radiographer's visual acuity.
- Visual acuity is the ability to resolve a spatial pattern in an image.
- The ability of an individual to detect discontinuities in radiography is also affected by the lighting condition in the place of viewing, and the experience level for recognizing various features in the image.
- The following material will help to develop an understanding of the types of defects found in weldments and how they appear in a radiograph.

- **Discontinuities**
- Discontinuities are interruptions in the typical structure of a material.
- These interruptions may occur in the base metal, weld material or "heat affected" zones.
- Discontinuities, which do not meet the requirements of the codes or specifications used to invoke and control an inspection, are referred to as defects.

## General Welding Discontinuities

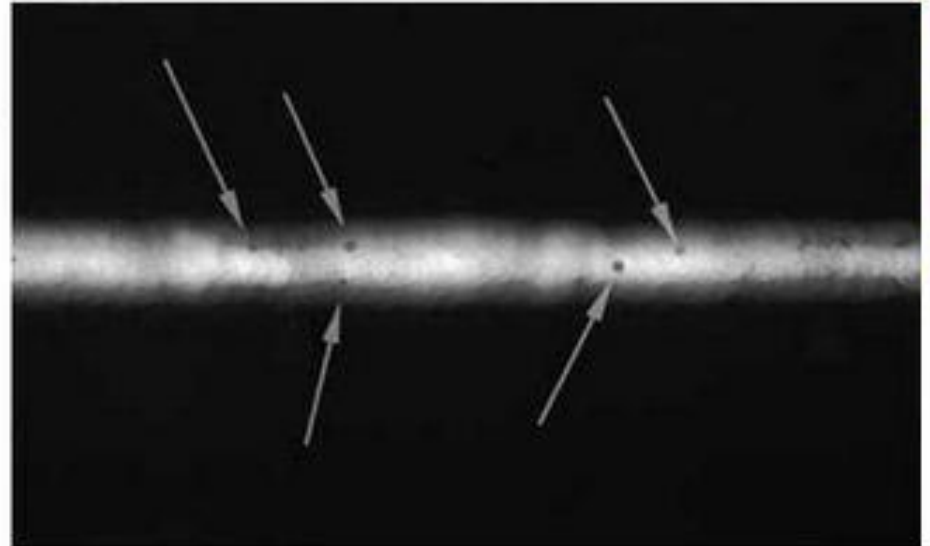
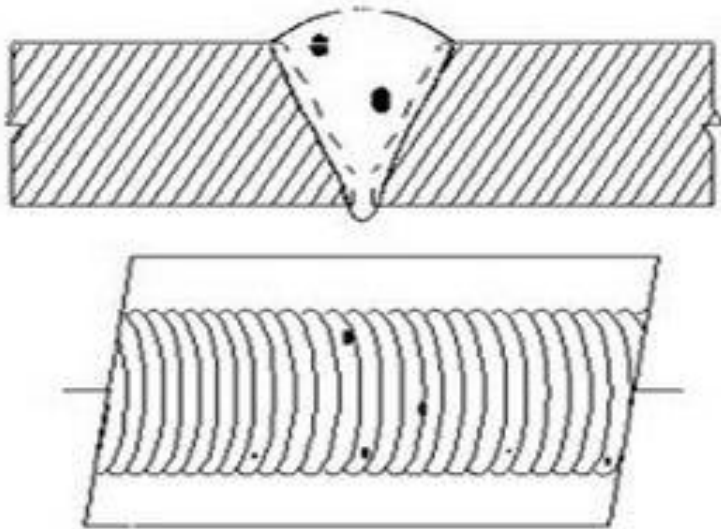
The following discontinuities are typical of all types of welding.

**Cold lap** is a condition where the weld filler metal does not properly fuse with the base metal or the previous weld pass material (interpass cold lap). The arc does not melt the base metal sufficiently and causes the slightly molten puddle to flow into the base material without bonding.

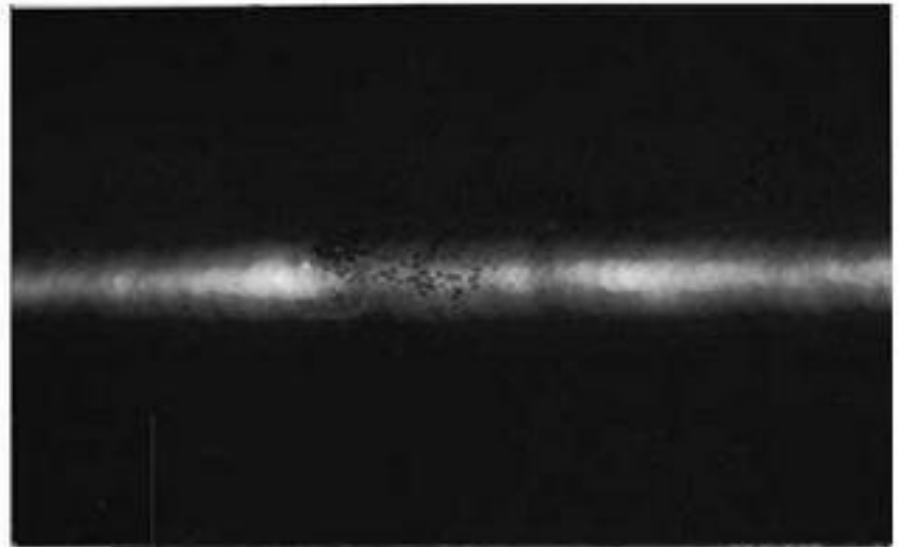
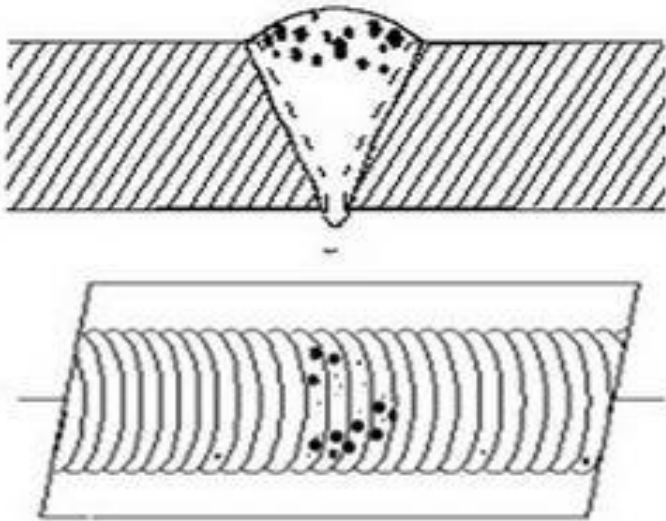




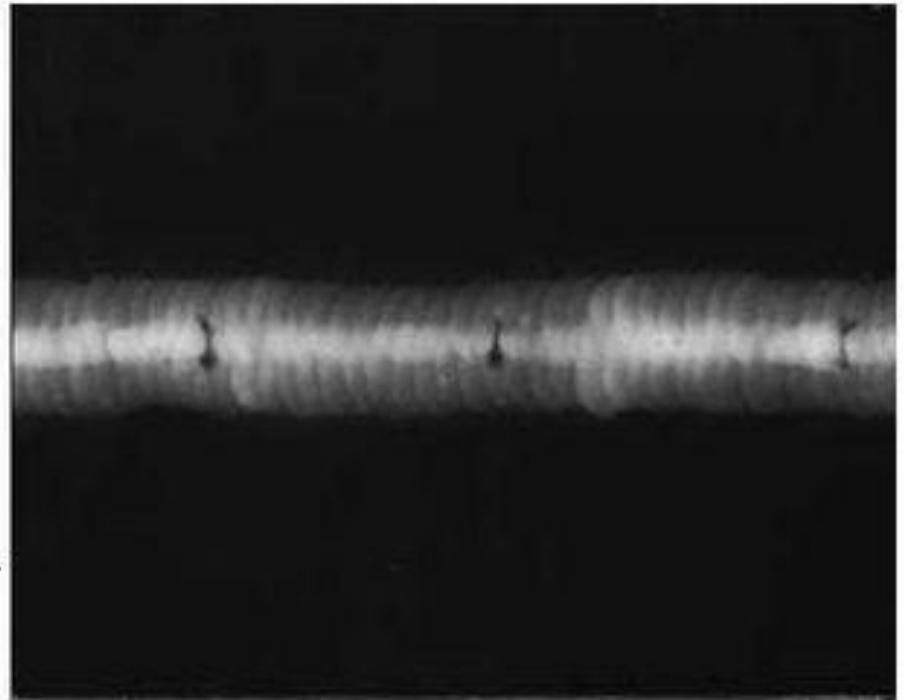
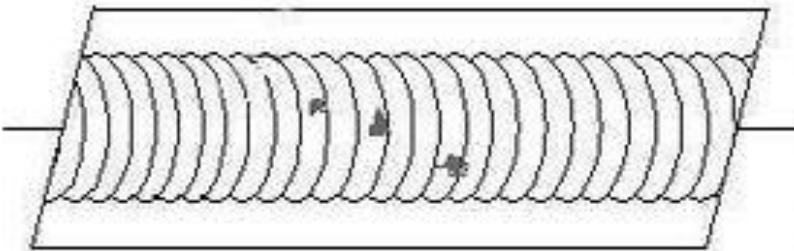
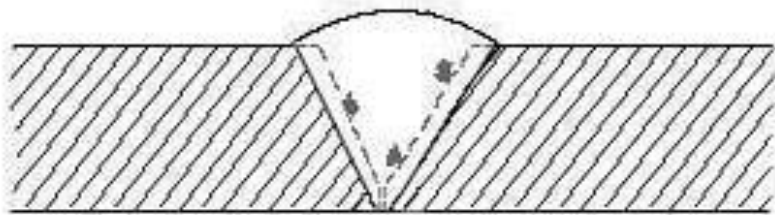
**Porosity** is the result of gas entrapment in the solidifying metal. Porosity can take many shapes on a radiograph but often appears as dark round or irregular spots or specks appearing singularly, in clusters, or in rows. Sometimes, porosity is elongated and may appear to have a tail. This is the result of gas attempting to escape while the metal is still in a liquid state and is called wormhole porosity. All porosity is a void in the material and it will have a *higher radiographic density than the surrounding area*.



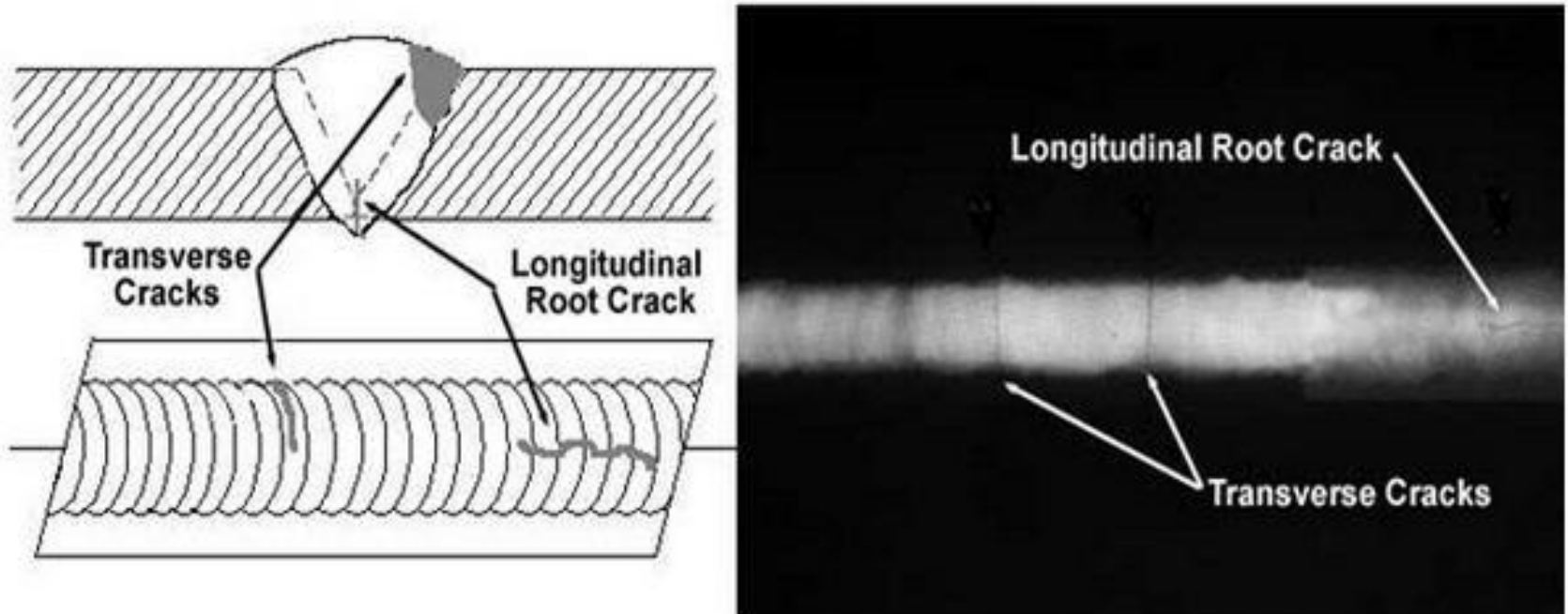
**Cluster porosity** is caused when flux coated electrodes are contaminated with moisture. The moisture turns into a gas when heated and becomes trapped in the weld during the welding process. Cluster porosity appear just like regular porosity in the radiograph but the indications will be grouped close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



**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.



**Cracks** can be detected in a radiograph only when they are propagating in a direction that produces a change in thickness that is parallel to the x-ray beam. Cracks will appear as jagged and often very faint irregular lines. Cracks can sometimes appear as "tails" on inclusions or porosity.

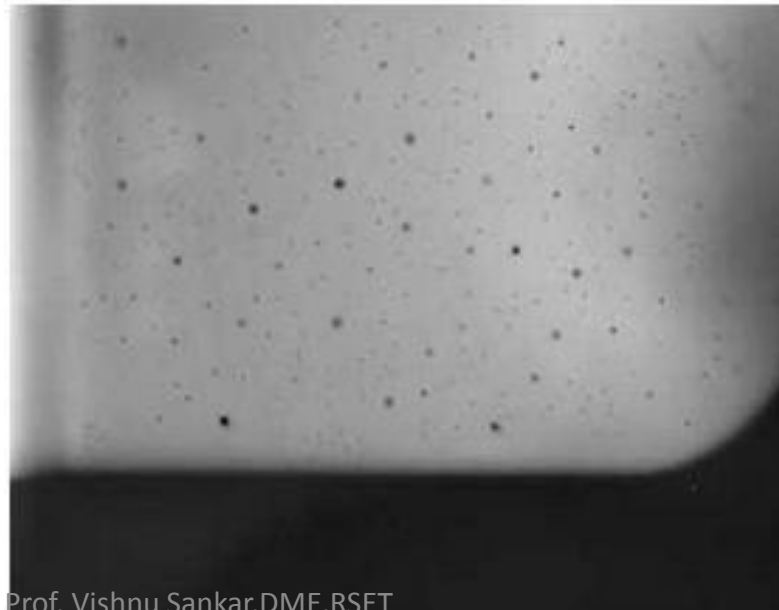


# Radiograph Interpretation - Castings

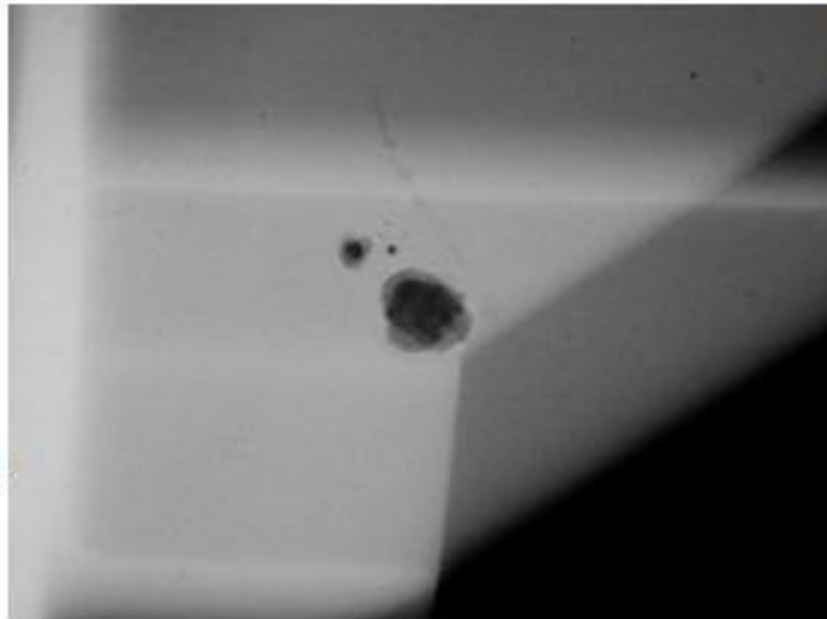
- The major objective of radiographic testing of castings is the disclosure of defects that adversely affect the strength of the product.
- Castings are a product form that often receive radiographic inspection since many of the defects produced by the casting process are volumetric in nature, and are thus relatively easy to detect with this method.
- These discontinuities of course, are related to casting process deficiencies, which, if properly understood, can lead to accurate accept-reject decisions as well as to suitable corrective measures.
- Since different types and sizes of defects have different effects on the performance of the casting, it is important that the radiographer is able to identify the type and size of the defects.
- ASTM E155, Standard for Radiographs of castings has been produced to help the radiographer make a better assessment of the defects found in components.
- The castings used to produce the standard radiographs have been destructively analyzed to confirm the size and type of discontinuities present.
- The following is a brief description of the most common discontinuity types included in existing reference radiograph documents (in graded types or as single illustrations).

## Radiographic indications for castings

**Gas porosity or blow holes** are caused by accumulated gas or air which is trapped by the metal. These discontinuities are usually smooth-walled rounded cavities of a spherical, elongated or flattened shape. If the sprue is not high enough to provide the necessary heat transfer needed to force the gas or air out of the mold, the gas or air will be trapped as the molten metal begins to solidify. Blows can also be caused by sand that is too fine, too wet, or by sand that has a low permeability so that gas cannot escape.

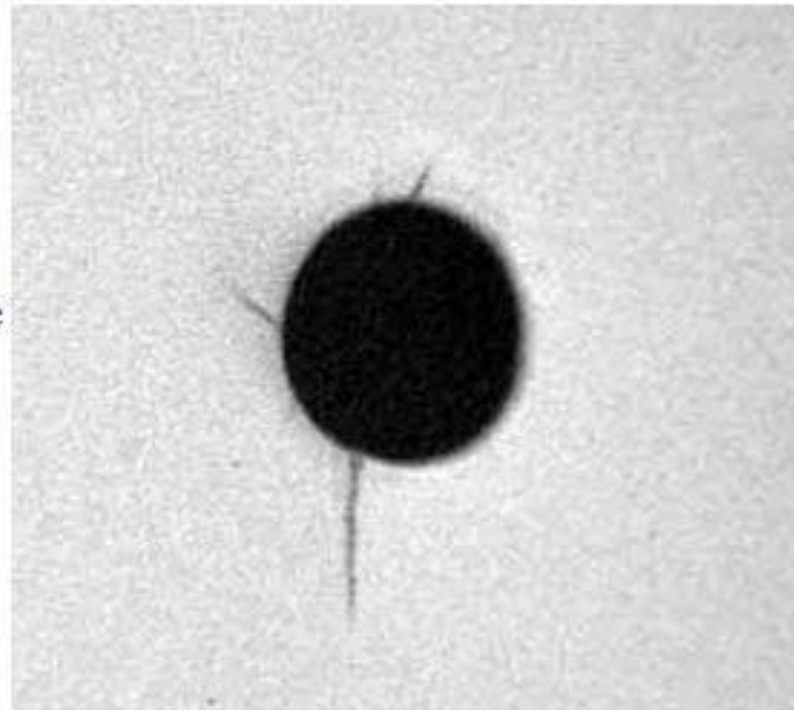


**Sand inclusions and dross:** are nonmetallic oxides, which appear on the radiograph as irregular, dark blotches. These come from disintegrated portions of mold or core walls and/or from oxides (formed in the melt) which have not been skimmed off prior to the introduction of the metal into the mold gates. Careful control of the melt, proper holding time in the ladle and skimming of the melt during pouring will minimize or obviate this source of trouble.



**Cracks** are thin (straight or jagged) linearly disposed discontinuities that occur after the melt has solidified. They generally appear singly and originate at casting surfaces.

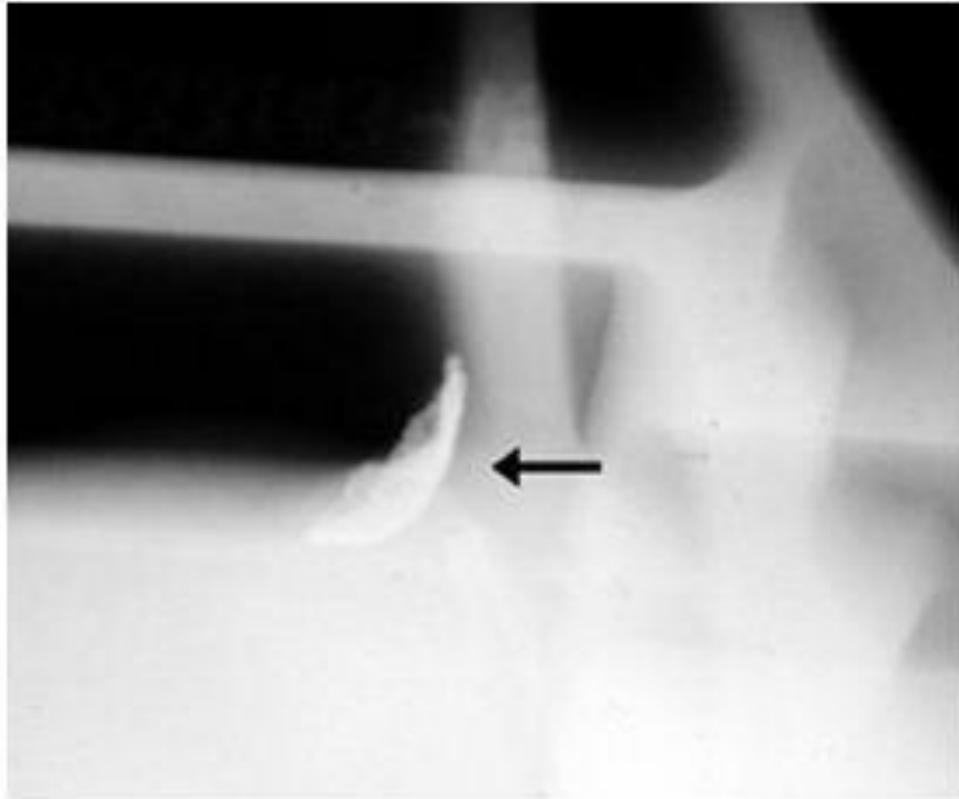
**Cold shuts** generally appear on or near a surface of cast metal as a result of two streams of liquid meeting and failing to unite. They may appear on a radiograph as cracks or seams with smooth or rounded edges.



Asst. Prof. Vishnu Sankar, DME, RSET



**Inclusions** are nonmetallic materials in an otherwise solid metallic matrix. They may be less or more dense than the matrix alloy and will appear on the radiograph, respectively, as darker or lighter indications. The latter type is more common in light metal castings.



# Safety aspects required in Radiography

- Radiation Health Risks
- The health risks associated with the radiation is considered to be one of the major disadvantages of radiography.
- The amount of risk depends on the amount of radiation dose received, the time over which the dose is received, and the body parts exposed.
- The fact that X-ray and gamma-ray radiation are not detectable by the human senses complicates matters further.
- However, the risks can be minimized and controlled when the radiation is handled and managed properly in accordance to the radiation safety rules.
- The active laws all over the world require that individuals working in the field of radiography receive training on the safe handling and use of radioactive materials and radiation producing devices.

- The occurrence of particular health effects from exposure to ionizing radiation is a complicated function of numerous factors.
- *Type of radiation involved.*
- All kinds of ionizing radiation can produce health effects.
- The main difference in the ability of alpha and beta particles and gamma and X-rays to cause health effects is the amount of energy they have.
- Their energy determines how far they can penetrate into tissue and how much energy they are able to transmit directly or indirectly to tissues.

- Size of dose received
- The higher the dose of radiation received, the higher the likelihood of health effects.
  
- Rate at which the dose is received
- Tissue can receive larger dosages over a period of time. If the dosage occurs over a number of days or weeks, the results are often not as serious if a similar dose was received in a matter of minutes.
  
- Part of the body exposed
- Extremities such as the hands or feet are able to receive a greater amount of radiation with less resulting damage than blood forming organs housed in the upper body.

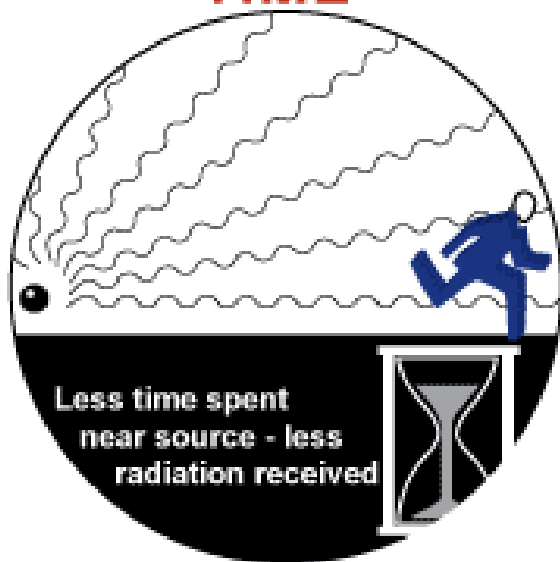
- The age of the individual
- As a person ages, cell division slows and the body is less sensitive to the effects of ionizing radiation. Once cell division has slowed, the effects of radiation are somewhat less damaging than when cells were rapidly dividing.
- Biological differences
- Some individuals are more sensitive to radiation than others. Studies have not been able to conclusively determine the cause of such differences.

# Controlling Radiation Exposure

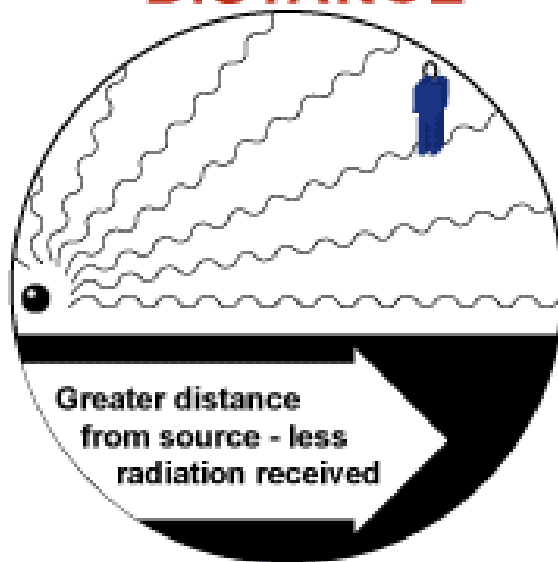
- When working with radiation, there is a concern for two types of exposure: acute and chronic.
- An acute exposure is a single accidental exposure to a high dose of radiation during a short period of time.
- Chronic exposure, which is also sometimes called “continuous exposure”, is long-term, low level overexposure.
- Chronic exposure may result in health effects and is likely to be the result of improper or inadequate protective measures.

- The three basic ways of controlling exposure to harmful radiation are:
- 1) limiting the time spent near a source of radiation,
- 2) increasing the distance away from the source,
- 3) and using shielding to stop or reduce the level of radiation.

## TIME



## DISTANCE



## SHIELDING





# Applications of Radiographic Testing

- Used to inspect most types of solid materials, both ferrous and non-ferrous alloys as well as non metallic materials and composites.
- Used to inspect the condition and proper placement of components, for liquid level measurement of sealed components etc.
- Used extensively for castings, weldments and forgings when there is a critical need to ensure that the object is free from internal flaws.
- Well suited to the inspection of semiconductor devices for detection of cracks, broken wires, unsoldered connections, foreign material and misplaced components, whereas other methods are limited in ability to inspect semiconductor devices

Thank you