BASIS OF DIAGNOSTIC RADIOLOGY

A Radiological examination is one of the most important diagnostic aids available in the medicalpractice. It is based on the fact that various anatomical structures of the body have differentdensities for the X-rays. When X-rays from a point source penetrate a section of the body, the internal body structures absorb varying amounts of the radiation. The radiation that leaves the body has a spatial intensity variation, i.e. an image of the internal structure of the body.

The commonly used arrangement for diagnostic radiology The X-ray intensity distribution is visualized by a suitable device like a photographic film. A shadow image is generated that correspondsto the X-ray density of the organs in the body section.

The examination technique varies according to the clinical problem.

The main properties of X-rays, which make them suitable for the purposes of medical diagnosis, are:

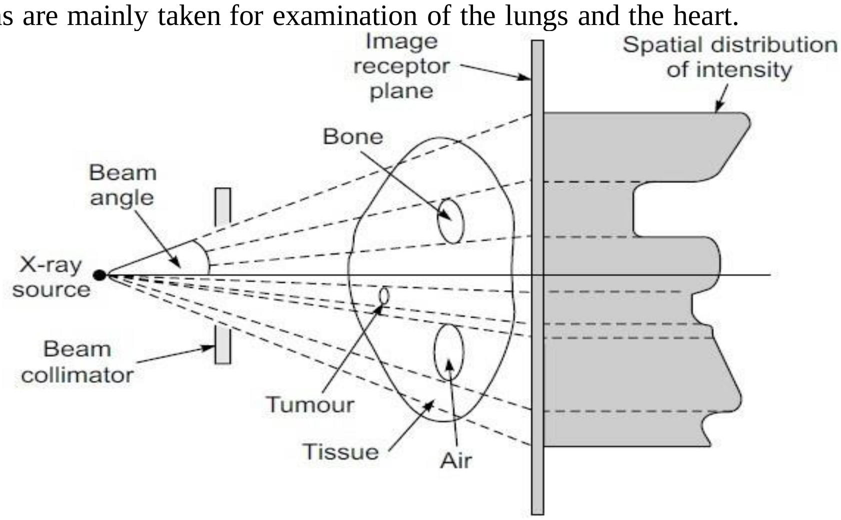
- Capability to penetrate matter coupled with differential absorption observed in various materials
- Ability to produce luminescence and its effect on photographic emulsions.

The X-ray picture is called a **Radiograph**, which is a shadow picture produced by X-rays emanating from a point source.

The X-ray picture is usually obtained on photographic film placed in the image plane.

The skeletal structures are easy to visualize and even the untrained eye can sometimes observe fractures and other bone abnormalities.

Chest radiographs are mainly taken for examination of the lungs and the heart.



➤ Fig. 19.1 *Basic set up for a diagnostic radiology image formation process*

Properties of X-ray

Because of short wavelength and extremely high energy, X-rays are able to penetrate throughmaterials which readily absorb and reflect visible light. This forms the basis for the use of X-rays for radiography and even for their potential danger. X-rays are absorbed when passing through matter. The extent of absorption depends upon the density of the matter. X-rays produce secondary radiation in all matter through which they pass. This secondary radiation is composed of scattered radiation, characteristic radiation and electrons. In diagnostic radiology, it is scattered radiation which is of practical importance.

X-rays produce ionization in gases and influence the electric properties of liquids and solids. The ionizing property is made use of in the construction of radiation-measuring instruments. X-rays also produce fluorescence in certain materials to help them emit light. Fluoroscopic screens and intensifying screens have been constructed on the basis of this property. X-rays affect photographicfilm in the same way as ordinary visible light.

X-ray imaging:

Properties of X-rays

- The X-rays in the medical diagnostic region have wavelength of the order of 10-l0m. They propagate with a speed of 3 x 1010 cm/ s and are unaffected by electric and magnetic fields.

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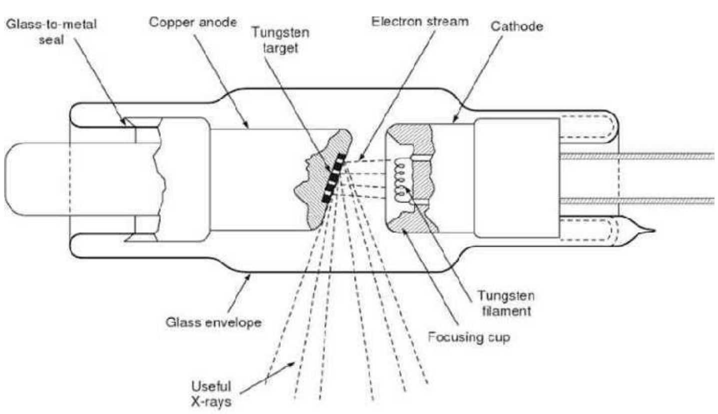
Production of X-rays

- X-rays are produced whenever electrons collide at very high speed with matter and are thus suddenly stopped. The energy possessed by the electrons appears from the site of the collision as a parcel of energy in the form of highly penetrating electromagnetic waves (X-rays) of many different wavelengths, which together form a continuous spectrum.
- X-rays are produced specially constructed glass tube, which basically comprises,

(i) a source for the production electrons,
(ii) a energy source to accelerate the electrons,
(iii) a free electron path,
(iv) a mean t focusing the electron beam and
(v) a device to stop the electrons.
Stationary mode tubes and rotating anode tubes are the two main types of X-ray tubes:

Stationary Anode Tube

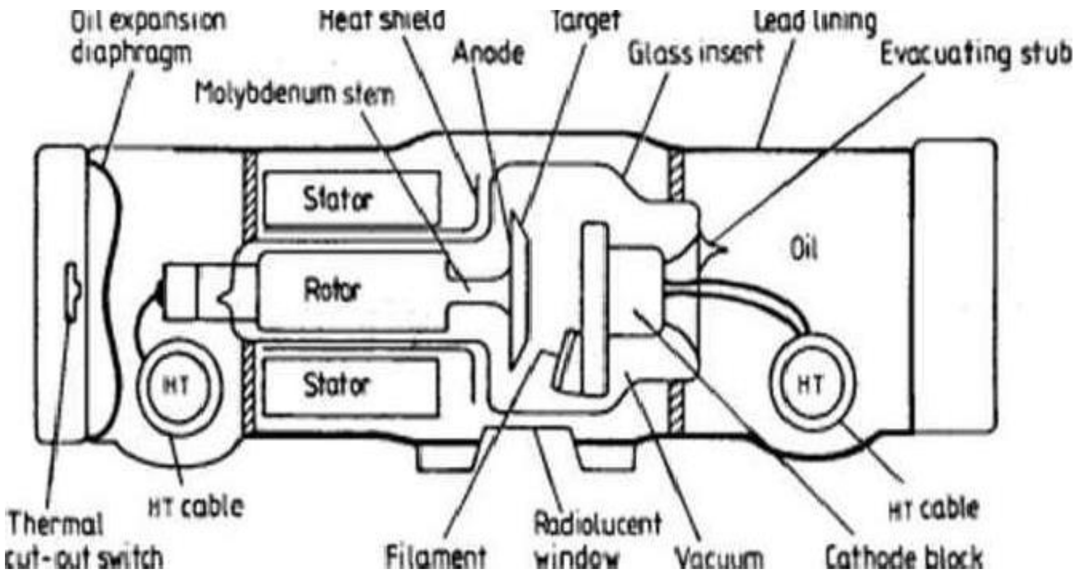
- the basic components of a stationary anode X-ray tube. The normal tube is a vacuum diode in which electrons are generated by thermionic emission from the filament of the tube.
- The electron stream is electrostatically focused on a target on the anode by means of a suitably shaped cathode cup.
- The kinetic energy of the electrons impinging on the target is converted into X-rays. Most electrons emitted by the hot element become current carriers across the tube.



➤ **Fig.** 19.2 *Construction of stationary anode X-ray tube*

- Some X-ray tubes function as a triode with a bias voltage applied between the filament and the cathode cup.
- The cathode block, which contains the filament, is usually made from nickel or from a form of stainless steel. The filament is a closely wound helix of tungsten wire, about 0.2 mm thick, thehelix diameter being about 1.0-1.5 mm.
- The target is normally comprised of a small tablet of tungsten about 15mm wide, 20mm long and 3mm thick soldered into a block of copper. Tungsten is chosen since it com bines a high atomic number (74)—making it comparatively efficient in the production of X-rays. It has a high melting point (3400°C) enabling it to withstand the heavy thermal loads.
- Copper being an excellent thermal conductor, performs the vital function of carrying the heat rapidly away from the tungsten target. The heat flows through the anode to the outside of the tube, where it is normally removed by convection. Generally, an oil environment is provided for convection current cooling.
- In addition, the electrodes have open high voltages on them and must be shielded. The tube will emit X-rays in all directions and protection needs to be provided except where the useful beam emerges from the tube.
- In order to contain the cooling oil and meet the above-mentioned requirements, a metal container is provided for completely surrounding the tube. Such a container is known as a 'shield'.

Rotating Anode Tube



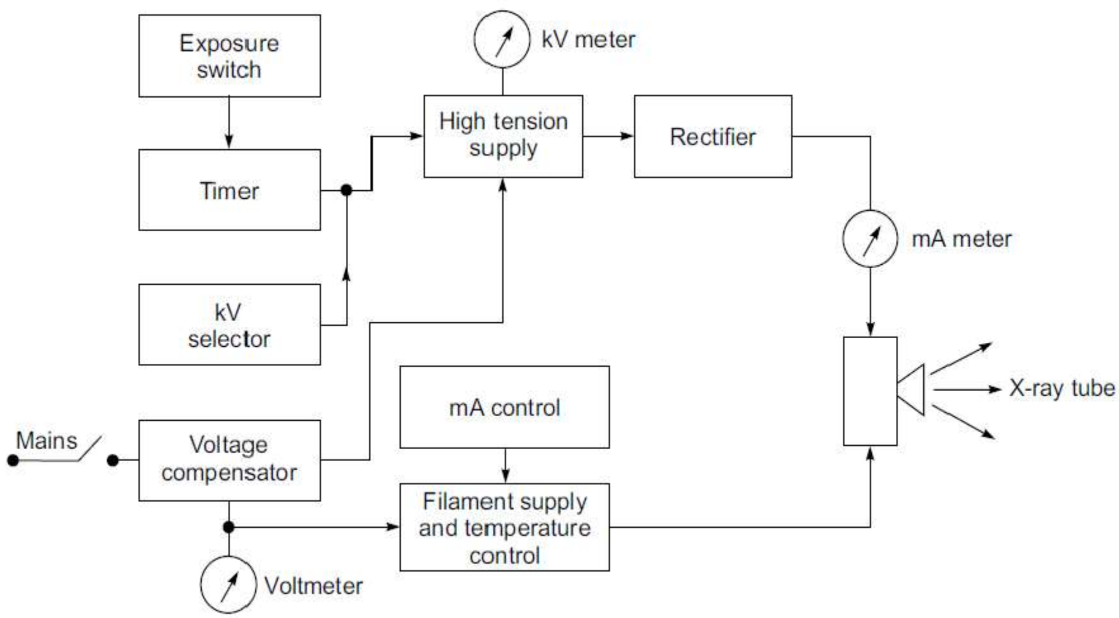
The filament is constructed from a spiral of tungsten wire (melting point 3410 °C), which is set in a nickel block. This block supports the filament and is shaped to create an electric field that focuses the electrons into a slit beam.

- The anode has a bevelled edge, which is at a steep angle to the direction of the electron beam. The exit window accepts x-rays that are approximately at right angles to the electron beam so that the x-ray source as viewed from the receptor appears to be approximately square even though the electron beam impinging on the target is slit-shaped.
- The choice of the anode angle will depend upon the application, with the angle being varied according to the requirements of field and focal spot sizes and tube output. For general-purpose units, an angle

of about 17° is appropriate.

- Most of the energy in the electron beam is deposited in the target in the form of heat. The use of a slit source of electrons helps by spreading out the target area and this idea can be extended by using a rotating anode, so that the electron beam impinges on the bevelled edge of a rotating disc and the target area is spread out over the periphery of the disc.
- A rotation speed of about 3000 RPM and an anode diameter of 10 cm are used in general-purpose units.

X-RAY MACHINE



➤ Fig. 19.4 *Block diagram of an X-ray machine*

Parts

1. X-Ray tube
2. High Tension Supply
3. Collimator
4. Patient Table.
5. Grid.
6. Radiographic film

1. X ray Tube

It is an important component of x-ray machine which is inaccessible as it is contained in a protective housing. It is a vacuum tube.

There are two primary parts.

1) Cathode
2) Anode.

2. Operating Console

It is an apparatus in X-Ray machine that allows to control the x-ray tube current and voltage.

The Console Controls are: -

1. Voltage compensator.
2. kV Meter.
3. mA Meter.
4. Exposure time.

1. Voltage Compensatr

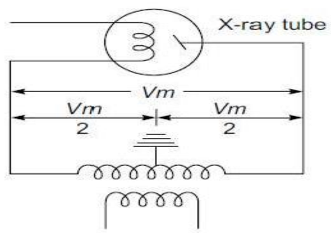
Because of variations in power distribution to the hospital and in power consumption by the various sections of the hospital, the voltage to the x-ray unit may vary by 5%, which will result in large variations in x-ray output.

High Tension Supply with Rectifier

Power supply system consists of Autotransformer

- The power supplied to x-ray machine is delivered to a special transformer called an Autotransformer. It works on the principle of electromagnetic induction but is very different from conventional transformer.
- It has only one winding and one core. The single winding has number of connections, or electric taps. The purpose to use the Autotransformer is to overcome induction losses. Its value ranges from
- Used for producing high voltage which is applied to the tube's anode and cathode and comprises a high voltage step-up transformer followed by a rectifier.

Self-Rectification Circuit for High Voltage Generation



➤ Fig. 19.5 *Self-rectified circuit for high voltage generation*

The high voltage is produced using a step-up transformer whose primary is connected to auto-transformer. The secondary of the H.T. transformer can be directly connected to the anode of the x-ray tube which will conduct only during the half cycles when the cathode is negative with respect to anodeor target.

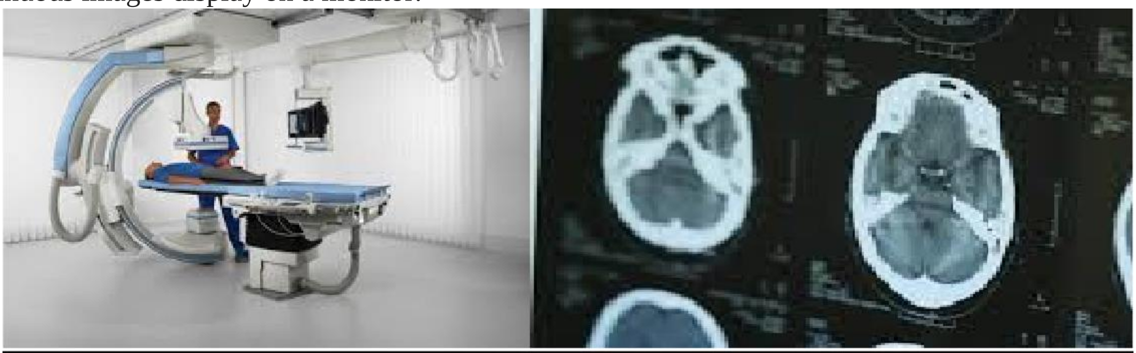
- The current through the tube follow, the H.T. pathway and is measured by a mA meter.
- A kV selector switch enables to change voltage between exposures. The voltage is measured with the help of a kV meter.
- The exposure switch controls the timer and thus the duration of the application of kV.
- To compensate for mains voltage variations, a voltage compensator is used in the circuit.
- The filament is heated with 6 to 12 V of ac supply at a current of 3 to 5 amperes. The filament temperature determines the tube current or mA, and, therefore, the filament temperature control has an attached mA selector. The filament current is controlled by using, in the primary side of the filament transformer, a variable choke or a rheostat. The rheostat provides a stepwise control of mA and is most commonly used in modem machines.
- These machines have maximum tube currents of about 20 mA and a voltage of about 100 kV. When self-rectification is used, it is necessary to use a parallel combination of a diode and resistance, in series with the primary of the H.T. transformer for suppressing higher inverse voltage likely to appear during the non-conducting half-cycle of the x-ray tube. This helps to reduce the cost and complexity of the x-ray machines.
- A preferred method of providing high voltage dc to the anode of the x-ray tube is by using a bridge rectifier using four valve tubes or solid-state rectifiers. This results in a much more efficient system than with half wave of self-rectification methods.
- The kV meter is connected across primary of the H.T. transformer. It actually measures volts whereas it is calibrated in kV by using an appropriate multiplication factor of turns-ratio of the transformer.
- In order to obtain the load voltage which varies with the tube current, a suitable kV meter

compensation is provided in the circuit. The kV meter compensator is ganged to the mA selector mechanically. Therefore, the mA is selected first and the kV setting is made afterwards during operation of the machine

- Moving coil meters are used for making current **I** (mA) measurements, for shorter exposures, amAs meter is used which measures the product I of mA and time in seconds.
- The exposure time is generally controlled by using some form of timing arrangement coupled with a contactor which supplies the H.T. to the anode of the x-ray tube only during that time.
- **Collimator:** The Collimator is attached to the x-ray tube below the glass window where the useful beam is emitted. Lead shutters are used to restrict the beam. Its purpose is to minimize field of view, to avoid un necessary exposure by using lead plates.
- **Grid:** By virtue of function and material, collimator and grid are same but they have different location. It is made up of lead. It is located just after patient. It is used to destroy scatteredradiation from the body.
- **Radiographic Film:** Two types of x-ray photon are responsible for density, contrast and image on
a radiograph. Those that pass t rough the patient without interacting and those that are scattered in
the patient through Compton interaction. Together these x-rays that exit from the patient andintersect the film are called Remnant x-rays

Fluoroscopy

The fluoroscopy procedure is an imaging technique that gathers real-time moving images using a fluoroscope of internal structures of patients. A fluoroscope consists of a fluorescent screen and an x- ray beam passing through your body. It mimics an x-ray movie, where continuous images display on a monitor.



Fluoroscopy is extremely helpful to surgeons while they're performing surgical procedures. It enables doctors to see moving structures of the body and helps with diagnosing diseases. Fluoroscopy offers enormous benefits over invasive surgical procedures since it requires a tiny incision, significantly reducing your risk of infection and recovery time.

Fluoroscopic Equipment

- High Voltage Generator
- X-Ray Tube (XRT)
- X-Ray Image Intensifier (XRII)

- Video Camera

XRII converts: low intensity X-ray photon fluence to high fluence of Visible Photons
Video Camera captures the XRII output image, and converts it to an analogue electrical signal thatconforms to a recognized video format (e.g. NTSC/PAL/SECAM)
Modern Video Cameras - Charge-Coupled Device (CCD)

Fluoroscopy uses:

- **Orthopaedic surgery:** Surgery concerned with musculoskeletal system conditions.
- **Catheter insertion:** Inserting a tube into the body.
- **Blood flow studies:** Visualizing the flow of blood to the organs.
- **Enemas:** Inserting a rubber tip into the rectum.
- **Angiography:** x-rays of lymph or blood vessels, including heart, leg and cerebral vessels.
- **Urological surgery:** Surgery of the urinary tract and sex organs.
- **Pacemaker implantation:** Implanting a small electronic device in the chest.

Risk

There are some minor risks associated with fluoroscopy. Because it uses x-ray technology, you havesome radiation exposure. The amount you absorb varies depending on the procedure length and your

size. Some individuals could experience radiation-induced injury to their skin that results in "burns" oftheir skin tissue.

Fluoroscopy Techniques

- **Barium X-rays:** Fluoroscopy is used in barium x-rays to allow the doctor to see the movement asthe intestines move the barium through them.
- **Electrophysiologic procedures:** With an electrophysiologic procedure, the doctor uses fluoroscopyto treat patients with irregular heartbeats.
- **Cardiac catheterization:** In this procedure, the doctor uses fluoroscopy to help them see the bloodflow through the coronary arteries, checking for arterial blockages.
- **Arthrography**: This is an x-ray to view one or more joints. Today, catheter arthrography is one ofthe major uses of chest fluoroscopy.
- **Hysterosalpingogram:** This procedure is an x-ray of the fallopian tubes and uterus.
- **Placement of IV catheters:** Catheters are hollow, thin tubes the doctor puts into your arteries or veins. When inserting the IV catheter, the doctor will use fluoroscopy to guide the catheter inside your body into a specific location.
- **Percutaneous kyphoplasty/vertebroplasty:** A doctor uses this procedure to treat spinal vertebrae fractures.

- **Needle or transbronchial biopsies:** A doctor uses this procedure to obtain a biopsy of tissue from a lung.