Production of X-ray

X-rays are produced whenever high-speed electrons collide with a metal target.

Any x-ray tube must therefore contain

(a) a source of electrons,

(b) a high accelerating voltage, and

(c) a metal target.

(d) Furthermore, since most of the **kinetic energy of the electrons is converted into heat in the target**, the latter must be water-cooled to prevent its melting.

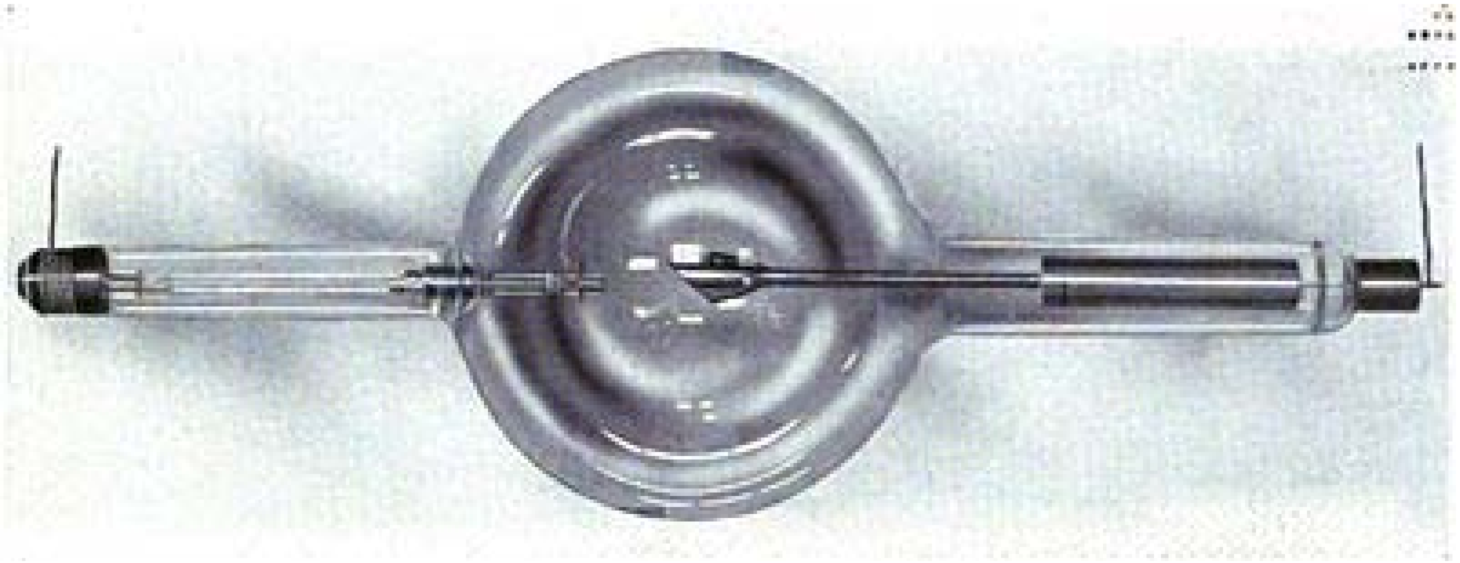
Anode- at ground potential

Cathode-normally of the order of **30,000 to 50,000** volts for diffraction work.

2 types of X-rays tubes are used:

1. Filament tubes, in which the source of electrons is a hot filament, and
2. gas tubes, in which electrons are produced by the ionization of a small quantity of gas in the tube.

X-ray Tube



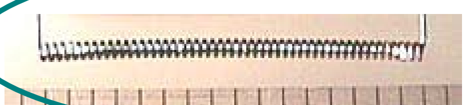
Coolidge X-ray tube, Invented in 1913. The heated cathode is on the left, and the anode is right. The X-rays are emitted downwards.

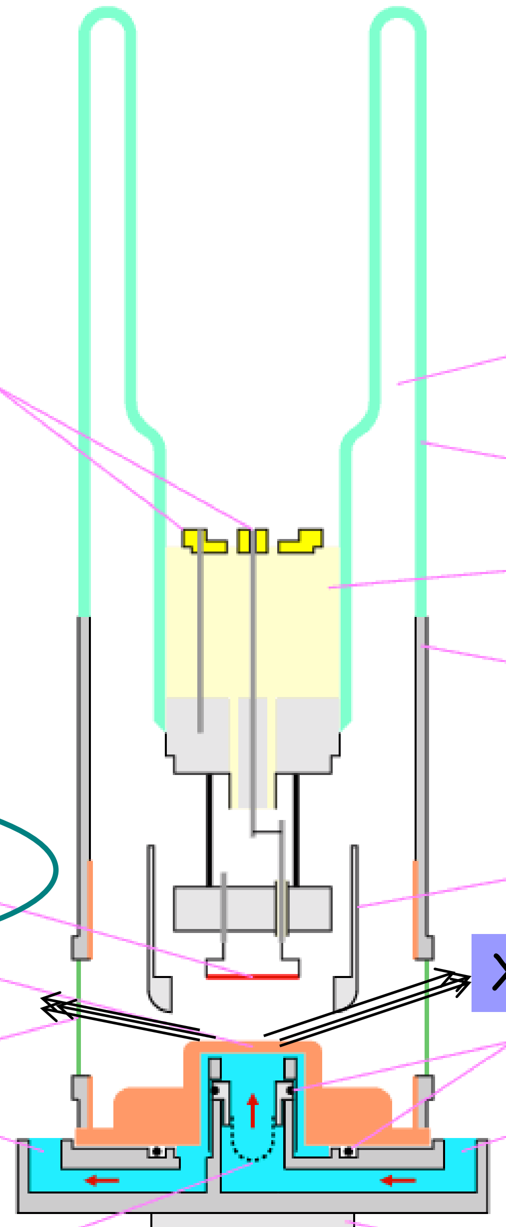
Modern X-ray Tube

Power rating
Tube current in mA
Tube voltage in kV

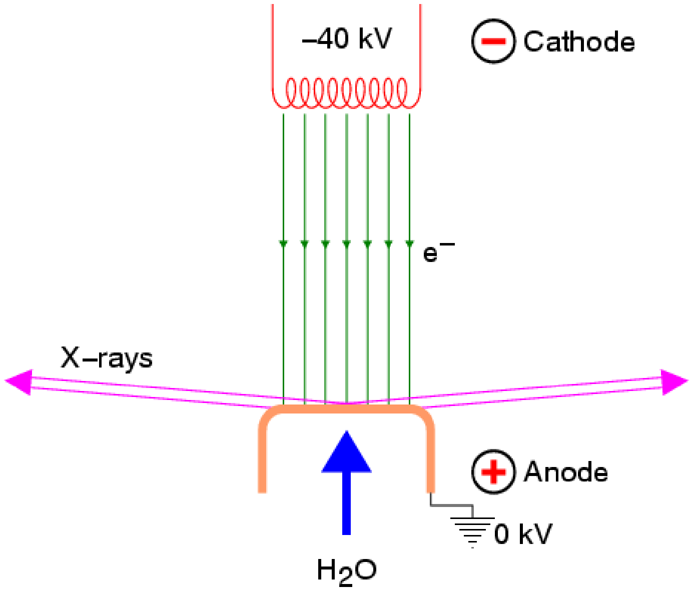
Tube current = 10-25mA

Filament current = 3amp

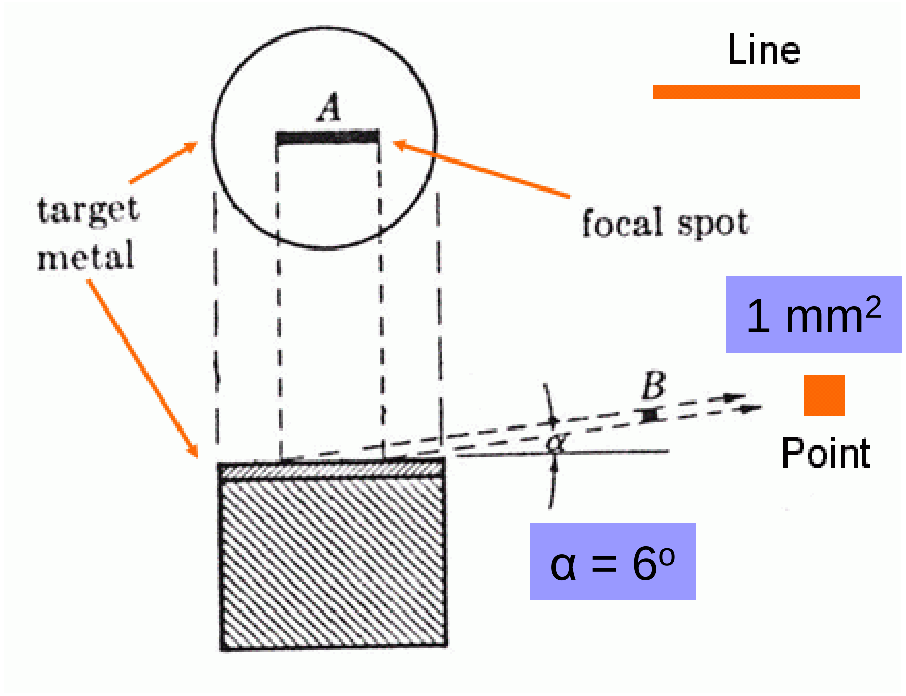




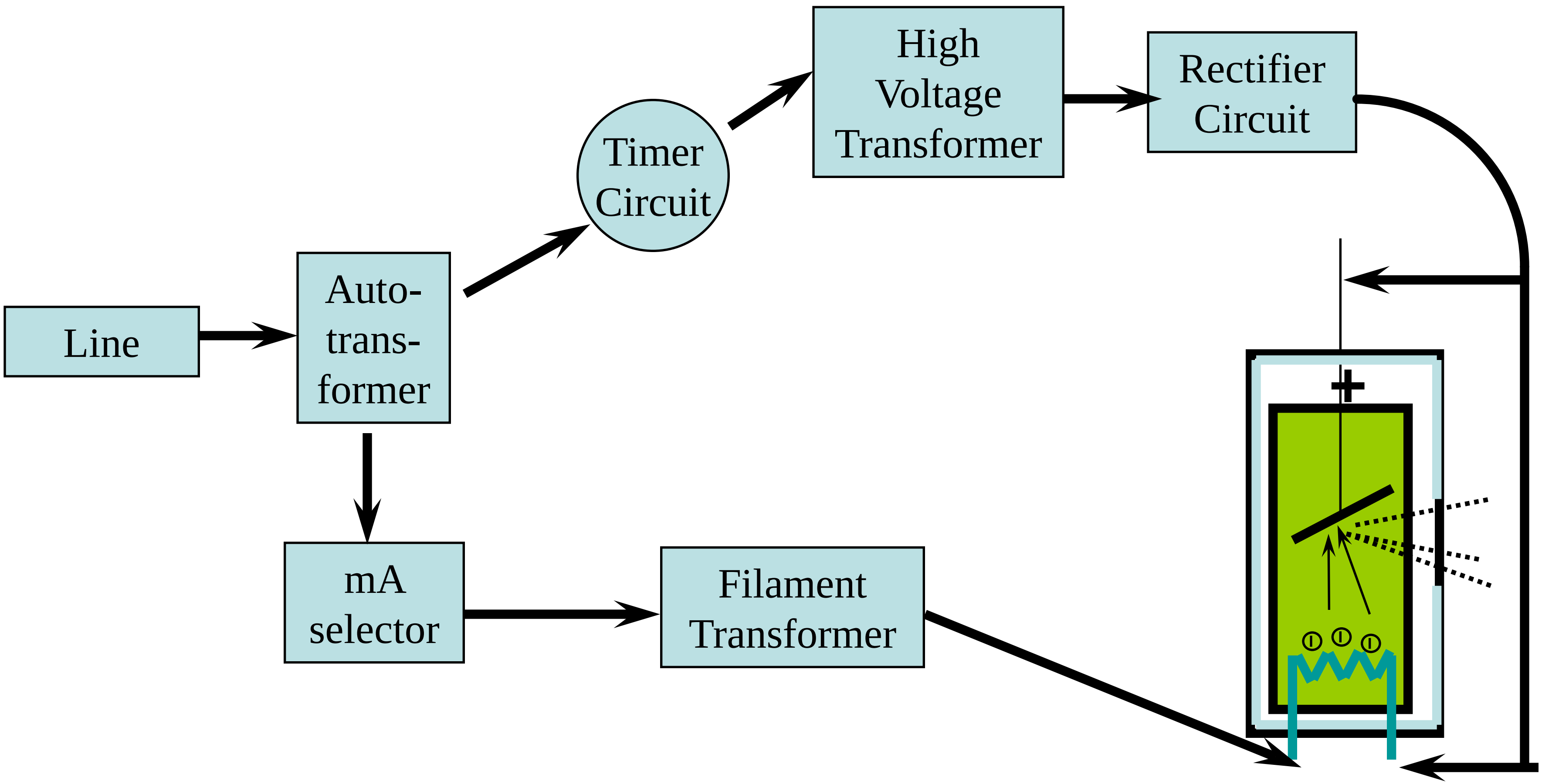
Simple schematic



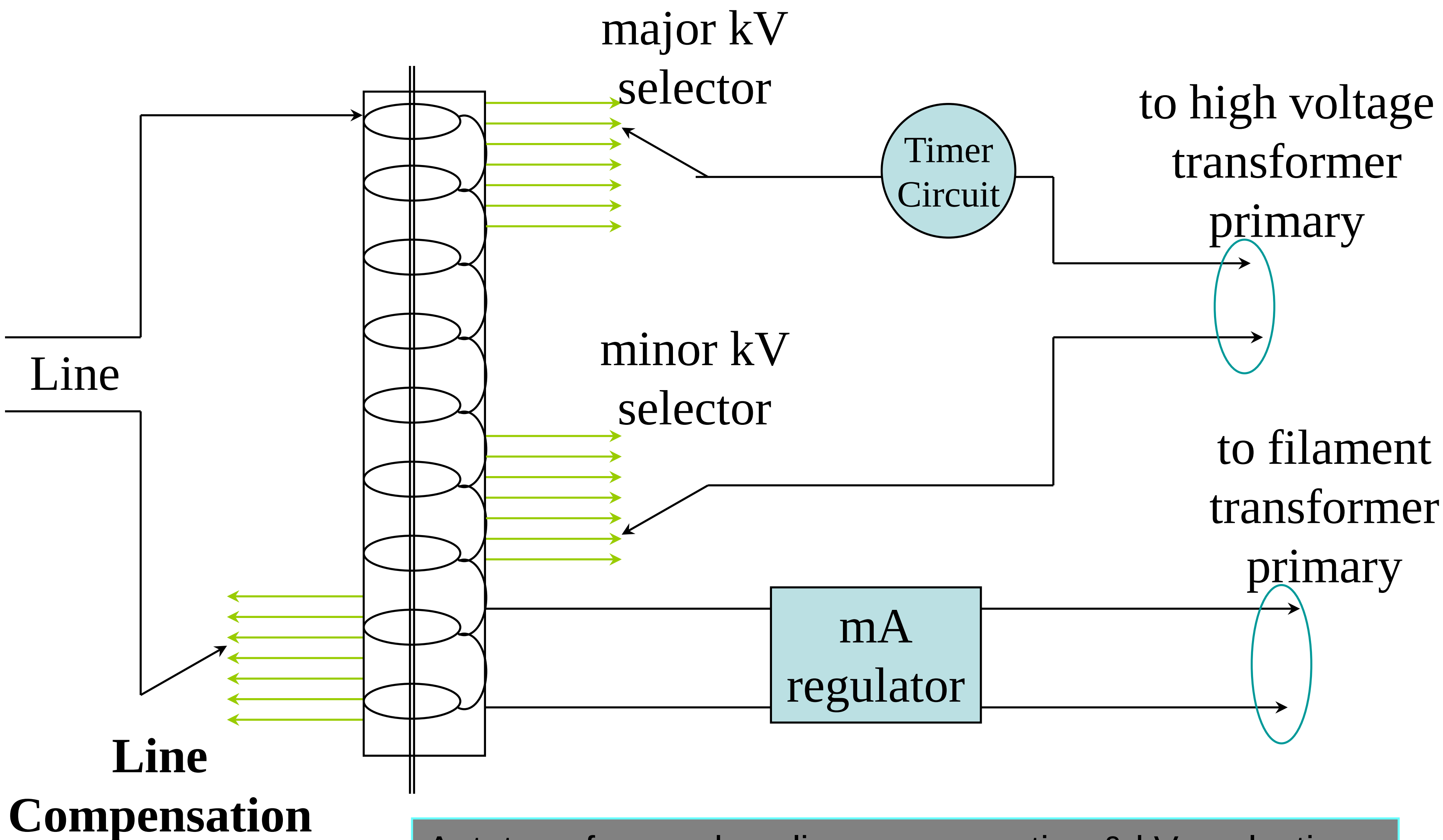
Source configuration



X-ray Circuit

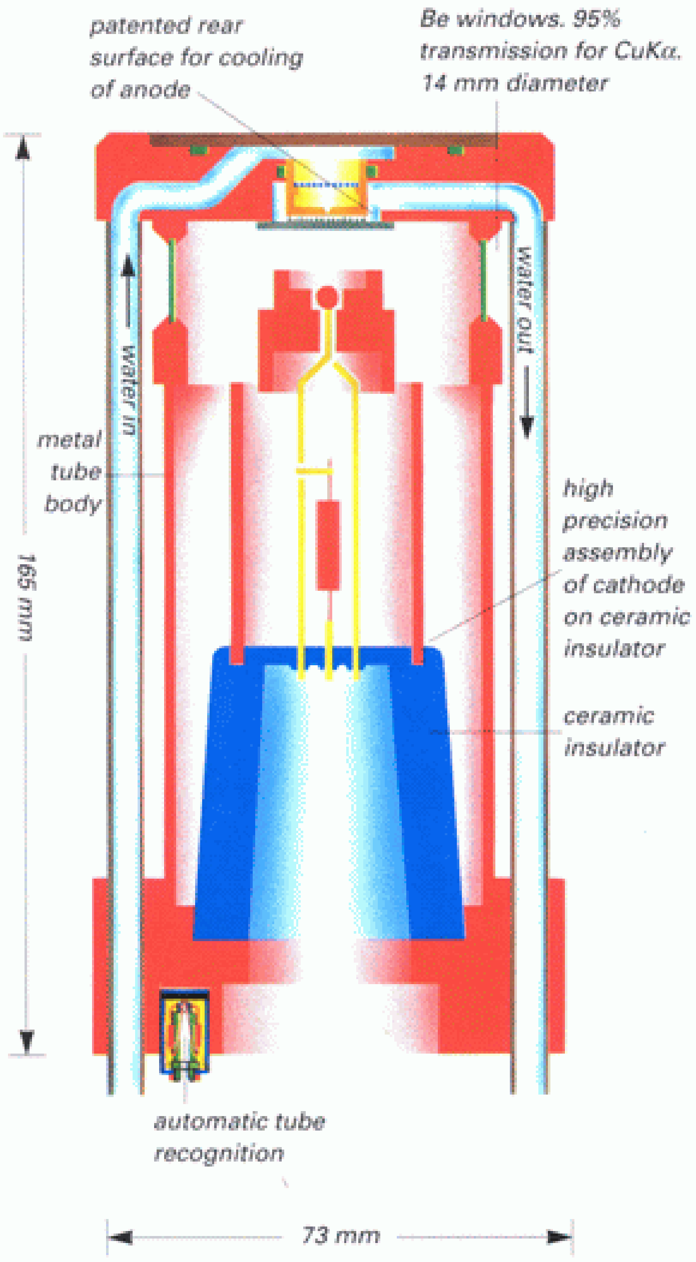


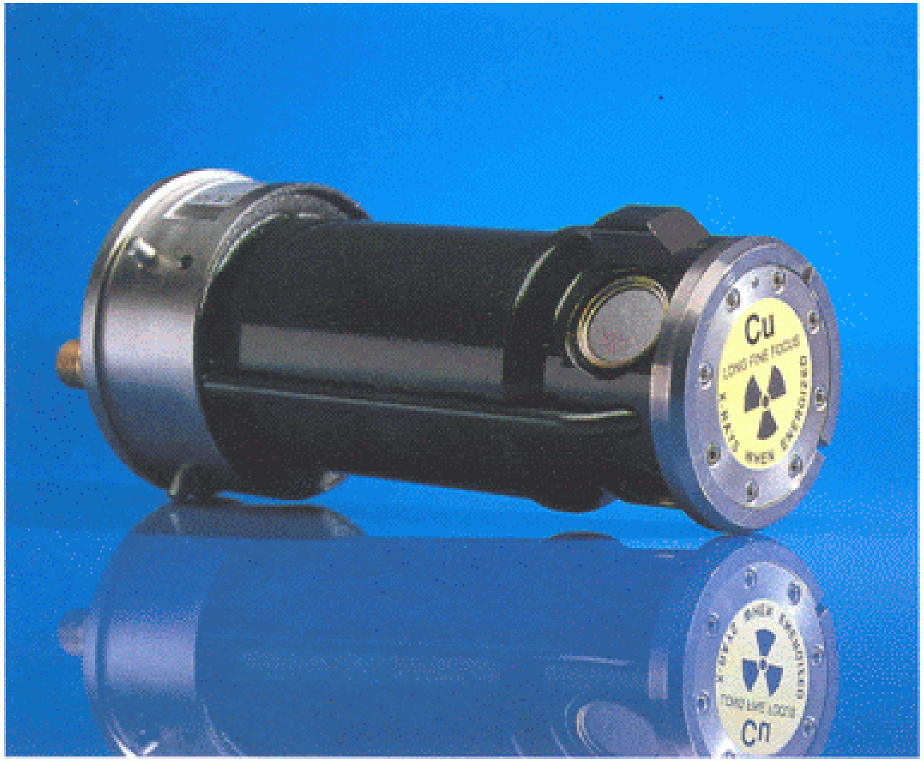
Autotransformer



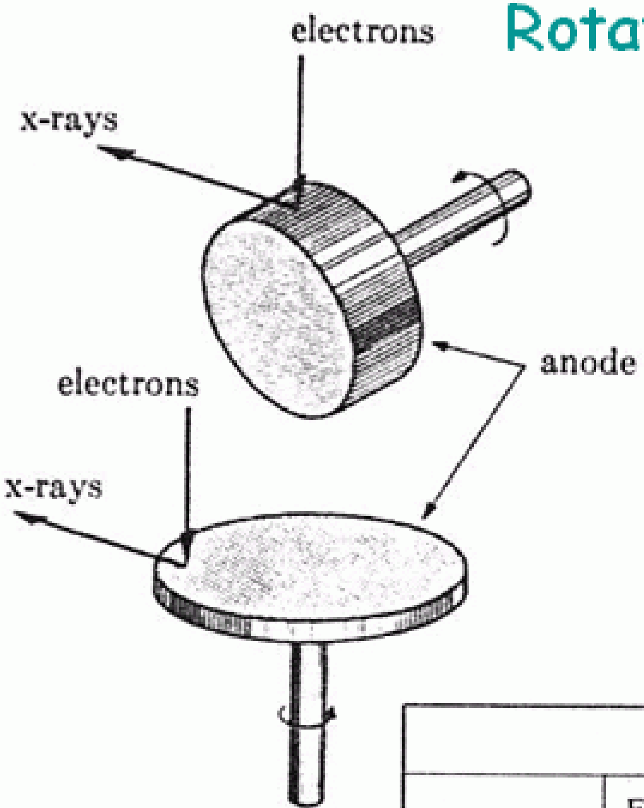
Autotransformer does line compensation & kVp selection

Ceramic X ray Tube





Rotating Anode X ray Generator



Intensities of diffracted x-ray beams are extremely low-

(a) only 1% efficient in x-rays production

(b) Diffraction is far less efficient

Rotating anode-5-10 times better

X-ray tube maximum ratings

Sealed-off (3 kW)*				Rotating anode (18 kW)†			
Anode	Focus (mm)	Power (kW)	Brightness (W mm^{-2})	Anode	Focus (mm)	Power (kW)	Brightness (W mm^{-2})
Mo	0.4×12 1×10 2×12	3.0 2.4 2.7	625 240 112	Mo, Cu	0.5×10 0.3×3 0.1×1	18.0 5.4 1.2	3600 6000 12000
Cu	0.4×12 1×10 2×12	2.2 2.0 2.7	460 200 112	Ag	0.5×10 0.3×3 0.1×1	12.0 5.4 1.2	2400 6000 12000
Cr	0.4×12 1×10 2×12	1.9 1.9 2.7	400 180 112	Cr	0.5×10 0.3×3 0.1×1	10.0 4.5 1.0	2000 5000 10000

* Philips.
† Rigaku.

Detection of X-rays

The principal **means** used to detect x-ray beams are

(a) fluorescent screens,

(b) photographic film, and

(c) Ionization devices.

Image storage plates (alternative to photographic film)

Fluorescent screens

It is made of a thin layer of zinc sulphide, containing a trace of nickel, mounted on a cardboard backing.

Under the action of x-rays, this compound fluoresces in the visible region, i.e., emits visible light, in **this case yellow light**.

fluorescent screens are widely used in diffraction work to **locate the position of the primary beam when adjusting apparatus**.

A **fluorescing c**rystal may also be used in conjunction with a phototube; the combination, called a **scintillation counter,** is a very sensitive detector of x-rays.

Photographic film

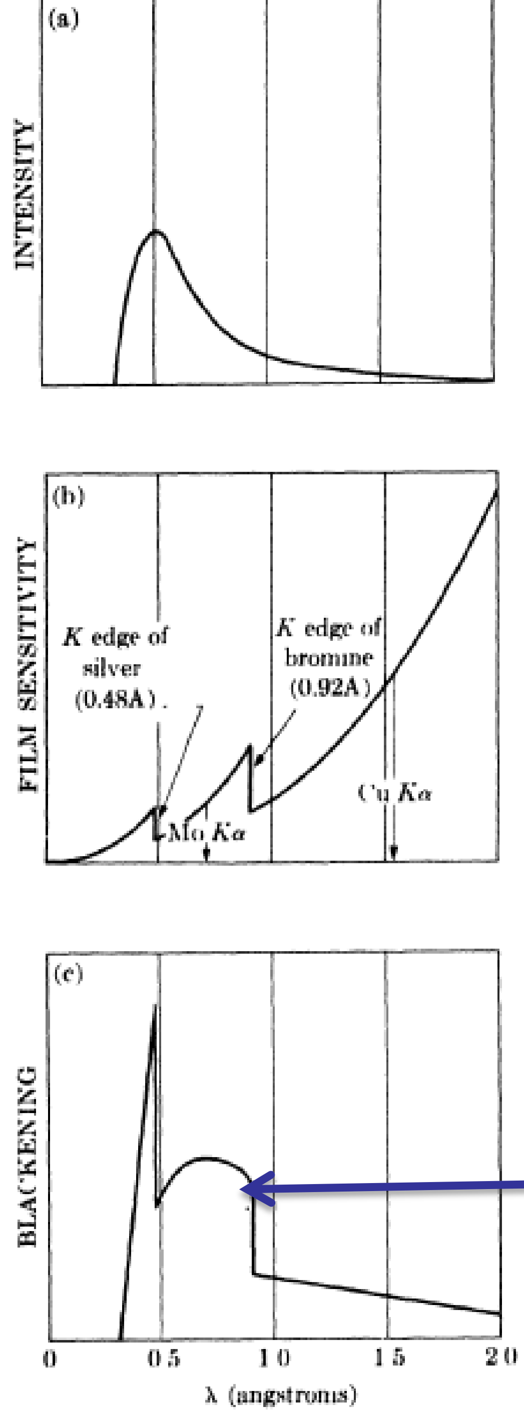
It is affected by x-rays in much the same way as by visible light, and film is the most widely used means of recording diffracted x-ray beams.

If, the emulsion on ordinary film is very thin, it cannot absorb much of the incident x-radiation, and

only **absorbed x-rays can be effective in blackening the film**.

For this reason, x-ray films are made with rather thick layers of emulsion on both sides in order to increase the total absorption.

The grain size is also made large for the same purpose: **this has the unfortunate consequence that x-ray films are grainy**, do not resolve fine detail, and cannot stand much enlargement.



Relation between film sensitivity and effective shape of continuous spectrum (schematic): (a) continuous spectrum from a tungsten target at 40 kV; (b) film sensitivity; (c) blackening curve for spectrum shown in (a).

Note, incidentally, how much more sensitive the film is to the K radiation from **copper than to the K** radiation from molybdenum, other things being equal.

effective photographic intensity" of the continuous spectrum.

Ionization devices

It measures the intensity of x-ray beams by the **amount of ionization** they produce in a gas.

X-ray quanta can cause ionization just as high-speed electrons can, namely, by knocking an electron out of a gas molecule and leaving behind a positive ion.

This phenomenon can be made the basis of intensity measurements **by passing the x-ray beam through a chamber containing a suitable gas and two electrodes having a constant potential difference between them.**

The **electrons are attracted to the anode** and the positive ions to the cathode and a current is thus produced in an external circuit.

In the ionization chamber, **this current is constant for a constant x-ray intensity,** and the **magnitude of the current is a measure of the x-ray intensity.**

In the **Geiger counter and proportional counter**, this current pulsates, and the **number of pulses per unit of time is proportional to the x-ray intensity.**

Summary of X-rays detection

fluorescent screens: **detection of x-ray beams**

photographic film and the various forms of counters: detection and measurement of intensity.

Photographic film: observing diffraction effects, **because it can record a number of diffracted beams at one time and their relative positions in space** and the film can be used as a basis for intensity measurements, if desired.

Intensities can be measured much more rapidly with **counters,** and these instruments are becoming more and more **popular for quantitative work**.
However, they **record only one diffracted beam at a time.**

Safety precautions

(i) electric shock and

(ii) radiation injury

hazards can be reduced to negligible proportions by proper **design of equipment** and **reasonable care on the part of the user.**

Cathode end must be inaccessible to the user during operation.

It should be installed in such way that it is impossible for the operator to touch the high-voltage parts without automatically disconnecting the high voltage.

Encased in a grounded metal covering, and
an insulated, shockproof cable connects the cathode end to the transformer.

The radiation hazard is due to the fact that x-rays can kill human tissue;

in fact, it is precisely this property which is utilized in x-ray therapy for the killing of cancer cells.

The biological effects of x-rays include burns (due to localized high-intensity beams), radiation sickness (due to radiation received generally by the whole body), and,

at a lower level of radiation intensity for a long duration, genetic mutations.

Burns may not be immediately felt as it is invisible. If the body has received general radiation above the tolerance dose, the first noticeable effect will be a **lowering of the white-blood-cell count,**

The safest procedure for the experimenter to follow is:

first, to locate the primary beam from the tube with a small fluorescent screen fixed to the end of a rod and thereafter avoid it;

second, to make sure that s/he is well shielded by lead or lead-glass screens from the radiation scattered

Last but not least, put specimen, start scanning and leave the room during operation.