

Filtration

When the x-ray beam is produced, much energy of photons exists. Many are of such low energies that they will offer nothing to the production of the radiograph. Metals such as aluminum will absorb the soft low energy rays. This reduces the patient exposure.

Metal filters, usually aluminum or copper, are inserted into the x-ray tube housing so that low-energy x-rays are absorbed before they reach the patient.

These x-rays have little diagnostic value. Low-energy x-rays do not contribute to the formation of an x-ray image; all they do is exposing the body to radiation. Therefore, we need to get rid of them.

The process of removing these low-energy x-rays from the x-ray beam is known as filtration, Or the process of attenuating and hardening an x-ray beam, Filtration increases the average energy (quality) of the x-ray beam.

Three types of x-ray filtration are used:

- ↳ **Inherent**
- ↳ **Added**
- ↳ **Compensating**

The inherent filtration, results from the materials present in the x-ray machine, x-ray tube, which the x-rays have to pass through.

These include:

- ↳ the beryllium window of the x-ray tube, is approximately 0.5 mm Al equivalent,
- ↳ the oil in the tube head

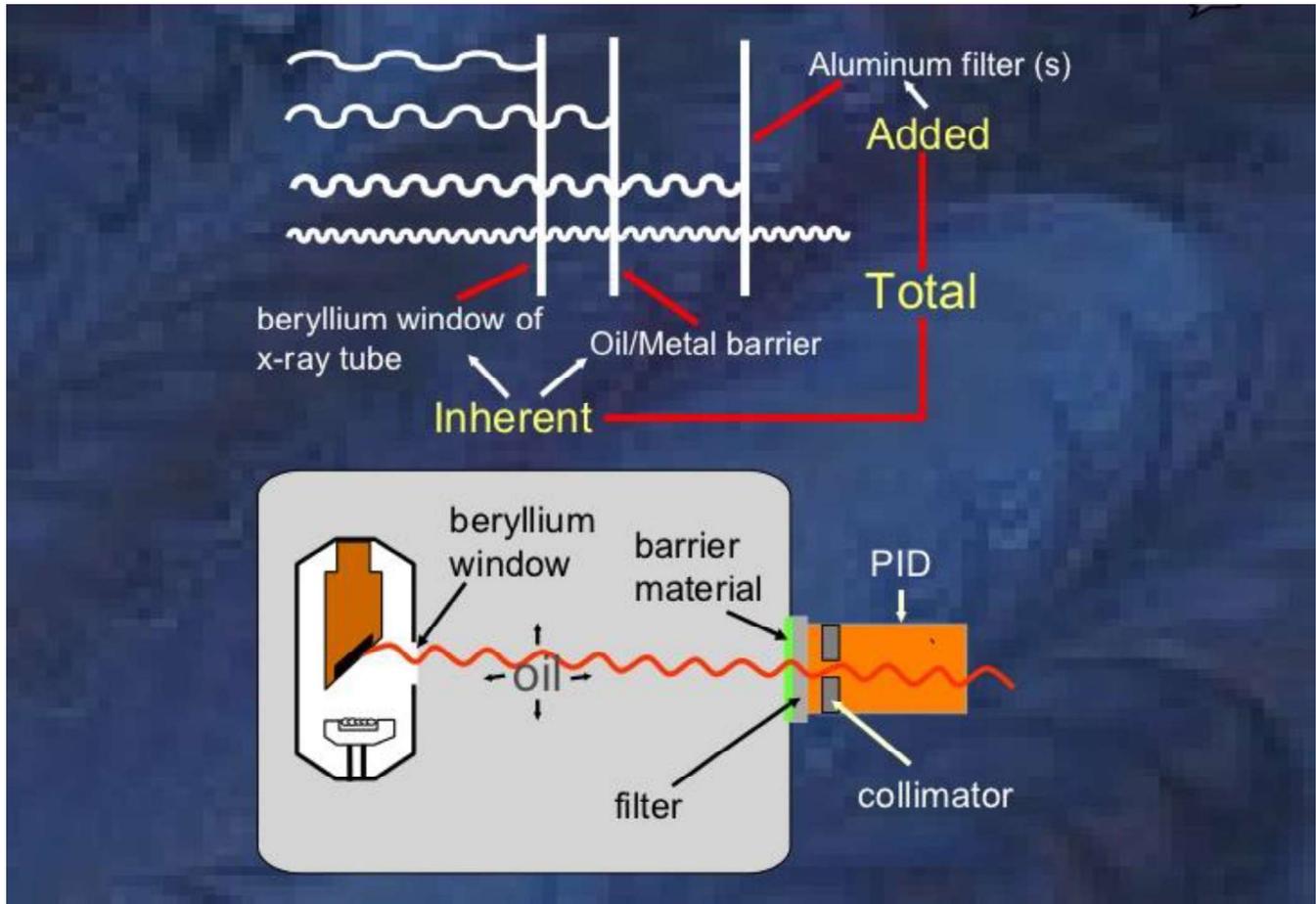
↳ and the barrier material that keeps the oil from leaking out of the tube head. This removes very weak x-rays.

With age, inherent filtration tends to increase because some of the tungsten metal of both the target and filament is vaporized and is deposited on the inside of the window.

Special-purpose tubes, such as those used in mammography, have very thin x-ray tube windows. They are sometimes made of beryllium ($Z = 4$) rather than glass and have an inherent filtration of approximately 0.1 mm Al.

Added Filtration, A thin sheet of Al positioned in the path of the x-ray beam, between the protective x-ray tube housing and the x-ray beam collimator .

These sheets remove the x-rays that had enough energy to get through the inherent filtration but are still not energetic enough to contribute to image formation. Sheets of varying thicknesses, when combined with the inherent filtration, produce the total filtration for the x-ray machine. Federal regulations require that an x-ray machine capable of operating at 70 kVp or higher must have total filtration of 2.5 mm aluminum equivalent. X-ray machines operating below 70 kVp need to have a total filtration of 1.5 mm aluminum equivalent.



Compensating filters: are shapes of aluminum mounted onto a transparent panel that slides in grooves beneath the collimator. These filters balance the intensity of the x-ray beam so as to deliver a more uniform exposure to the image receptor. For example, they may be shaped like a wedge for examination of the spine or like a trough for chest examination.

Some facilities may be set for higher filtration during examinations of tissue with high subject contrast, such as the extremities, joints, and chest. When properly used, higher filtration for these examinations results in lower patient radiation dose.

However, As filtration is increased, the result is increased x-ray beam quality and penetrability. The result on the image is the same as that for increased kVp, that is, more scatter radiation and reduced image contrast, and patient dose is reduced because fewer low-energy x-rays are found in the useful beam.

Calculation of the reduction in exposure requires knowledge of half-value layer (HVL),

Half-value layer or HVL

The concept of **half-value layer** or **HVL** is used to quantify the ability of an x-ray beam to penetrate the material being examined. The HVL of an x-ray beam is the amount or thickness of absorbing material or filtration that must be placed in the beam to reduce the transmission of the beam by one half, (*reduce the ray to half its original value*). It is related to linear attenuation coefficient (μ) with following formula:

$$\text{HVL} = 0.693 / \mu$$

This relationship comes from the intensity attenuation equation.

$$I = I_0 e^{-\mu x}$$

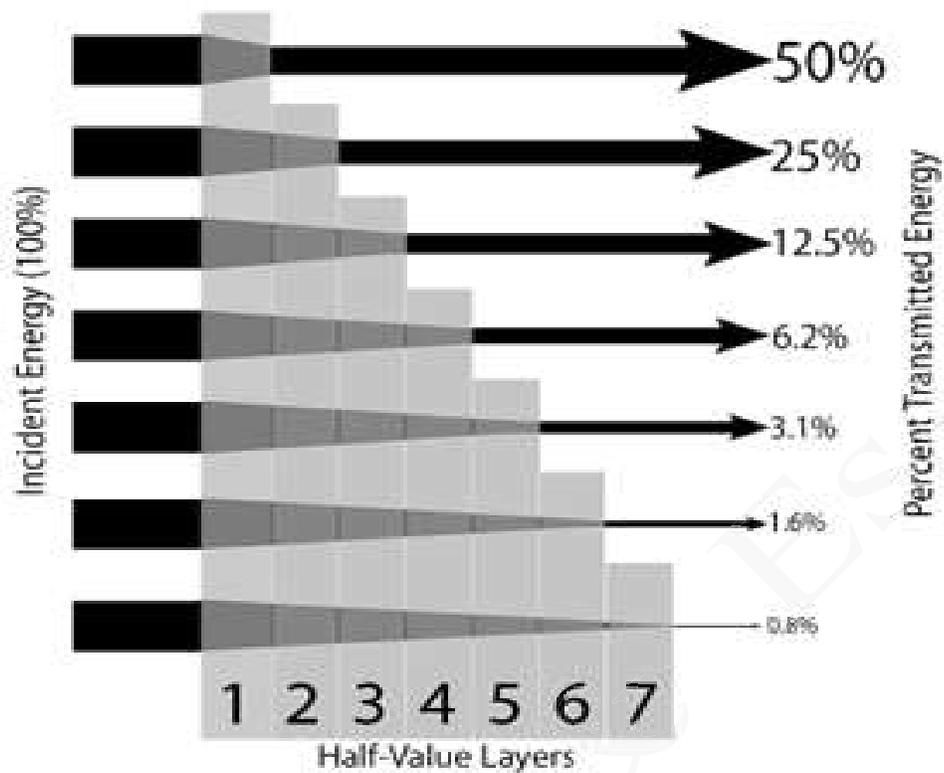
$$0.5 = 1.0 e^{-\mu x}$$

It can be seen that if an incident energy of 1 and a transmitted energy is 0.5 (1/2 the incident energy) is plugged into the equation, the thickness (x) multiplied by μ must equal 0.693 (since the number 0.693 is the exponent value that give a value of 0.5). X in this case is the half-value layer.

Example

What is the HVL for a material with an attenuation coefficient of 0.4/cm?

$$\text{HVL} = \frac{0.693}{0.4 / \text{cm}}$$
$$\text{HVL} = 1.73 \text{cm}$$



The material predominantly used to determine the HVL of diagnostic x-ray equipment is aluminum, and hence HVL is expressed in terms of mm of aluminum. Medical diagnostic x-ray machines typically have HVLs ranging from 2.3 to 5 mm Al.

Minimum Half-Value Layers of aluminum
for given X-ray tube voltages

X-ray Tube Voltage (kV)	Half-Value Layer of Aluminum (mm)
70	2.5
80	2.9
90	3.2
100	3.6
110	3.9
120	4.3
130	4.7
140	5.0
150	5.4

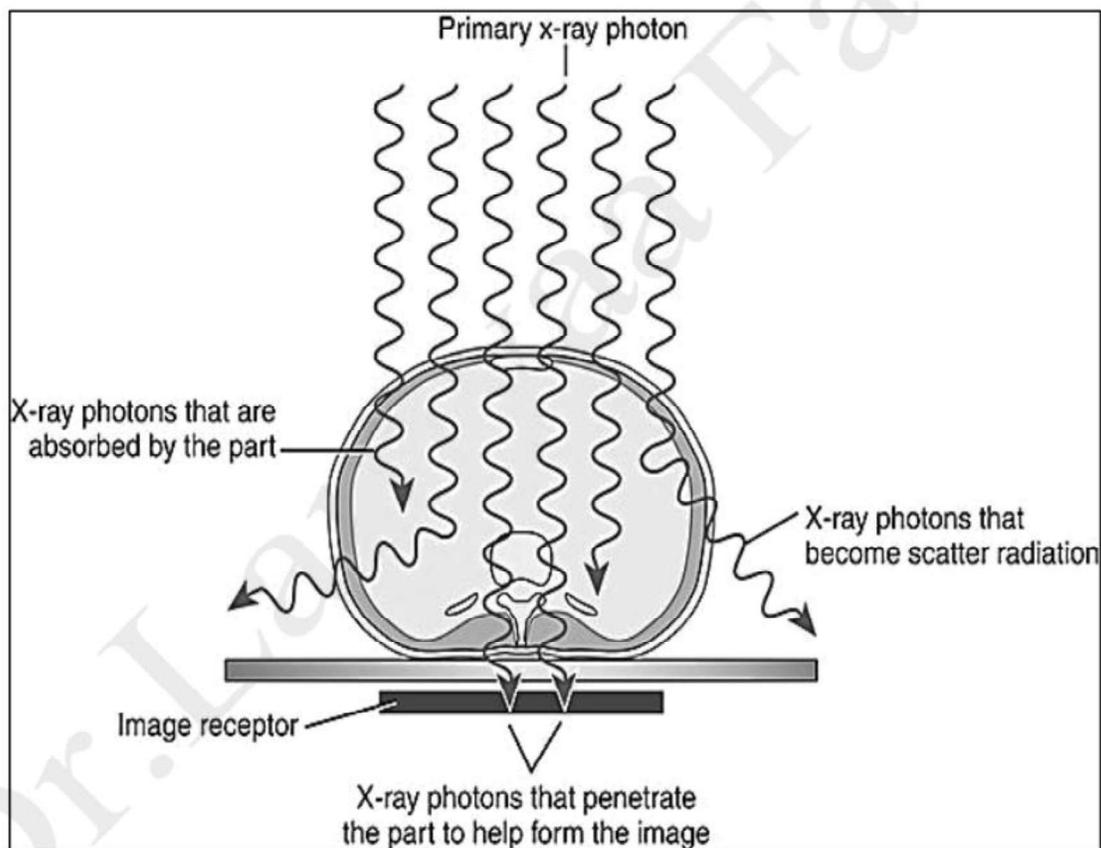
Aluminum filtration(mm)	Exposure dose to skin(mR)	Decrease in exposure dose(%)
None	2380	0
0.5	1850	22
3	465	80

The Scatter Radiation and methods of control it

When a radiographic exposure is performed, the primary photons will either:

- Pass through the body tissue unaffected. (without interacting).
- Become absorbed by the tissues within the body.
- Interact with body tissues and change direction (Compton's scatter).

X-rays that exit the patient interact with the IR are Image-forming x-rays



Scatter Radiation

By definition, “Scatter radiation occurs when radiation deflects off an object, causing x-rays to be scattered. It is important to keep in mind that scatter radiation has the ability to travel in all different directions,” In the case of X-rays, the most common source of scatter radiation for most humans, is the patient, and those scattered rays can continue to scatter around the room based on various design features.

Scatter radiation is probably the biggest single factor contributing to decreased film quality. It is the result of a redirection of the primary x-ray beam and production of new x-rays following the interaction with the patient. Therefore, scatter radiation is present in each radiographic examination. The effect of scatter radiation is to produce a generalized photographic fog on the film, which reduces the contrast between adjacent areas on the radiograph.

