Q.A. Collectible

Sponsored by CRCPD's Committee on Quality Assurance
in Diagnostic X-ray (H-7)

Beam Quality: Total Filtration and Half-Value Layer

Filtration, the process of attenuating and hardening an x-ray beam, is traditionally quantified in units of mm Al (aluminum) or the thickness of an aluminum filter that would have the same effect on the beam. The filtration provided by the x-ray tube housing assembly itself is termed the **inherent filtration.** In the case of a standard x-ray tube, the inherent filtration is approximately 0.5 mm Al and in special purpose tubes, such as those for mammography, it may be as low as approximately 0.1 mm Al. Material purposefully introduced into the beam to further reduce the presence of low energy x-rays relative to high energy x-rays (hardening the beam) is often referred to as **added filtration**. The sum of all the material the x-rays must pass through before emerging as the useful beam is termed the **total filtration**.

The x-rays produced at the anode pass through a variety of materials, starting with the glass envelope of the x-ray tube, before emerging from the machine as the useful beam. These materials attenuate primarily lower energy x-rays, but also reduce the quantity of x-rays at all energies. The preferential removal of low energy x-rays is usually regarded as beneficial, as the low energy x-rays:

- Cannot penetrate the object being examined to help produce the desired image,
- May degrade the image by increasing scatter, and
- Increase the dose delivered.

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. 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.

Total filtration and HVL are sometimes erroneously used interchangeably. They are not equivalent terms. The introduction of a known thickness of aluminum will not increase the HVL by a corresponding amount of millimeters of aluminum. For example, in the following table at 80 kVp, 1.5 mm Al total filtration results in an HVL of 1.8. An increase of 1 mm Al to a total of 2.5 mm Al changes the HVL to 2.4 mm, an increase of only 0.6 mm Al. While the total filtration doesn't typically change, the HVL measured will vary depending on the kVp and the type of high voltage generator (i.e., single phase, three phase, high-frequency, etc.) used in the machine.

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October, 2001

NOTE: The following table is provided to demonstrate how HVL varies with respect to total filtration and kVp. It is for single phase generators and is not appropriate for use with three phase or high-frequency systems.

Table: Half-Value Layer as a Function of Total Filtration and Tube Potential For a Single Phase Generator with Full Wave Rectification

Total filtration (mm Al)	Peak tube potential (kV)									
	30	40	50	60	70	80	90	100	110	120
0.5	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2
1.0	0.6	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8
1.5	0.8	1.0	1.3	1.4	1.6	1.8	1.9	2.1	2.3	2.4
2.0	0.9	1.2	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9
2.5	1.0	1.4	1.7	2.0	2.2	2.4	2.6	2.8	3.1	3.3
3.0	-	1.5	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.7
3.5	-	1.6	2.0	2.3	2.6	2.9	3.1	3.4	3.7	4.0

Appropriate tables for each generator type are available in various publications, including NCRP Report No. 102 (Medical X-ray, Electron Beam and Gamma-Ray Protection for Energies up to 50 MeV).

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