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Neutron Doors for High Energy Accelerators

Kersey determined empirically that the neutron dose equivalent (H_n) dominated the maze door shielding requirements for Betatron treatment rooms. Kersey found that the neutron dose equivalent leakage diffuses to the center of the maze as $(1/m_1)^2$, and subsequently reduces by a factor of 10 for every 5 meters from that point to the end of the maze. Kersey termed this maze neutron reduction component a Tenth Value Distance (TVD).

Kersey's method for Betatron treatment rooms is also applicable to linear accelerator treatment rooms. The Betatron rooms studied by Kersey had extremely high ceilings and the mazes had large cross sectional areas. The lower ceiling heights and smaller maze cross sectional areas found in linear accelerator treatment rooms result in Kersey's method being inaccurate for linear accelerator maze design. Work by Tesch and others shows that for linear accelerator treatment rooms, the first TVD is approximately 3 meters, with subsequent TVDs being 5 meters. This modification to Kersey's Betatron method is known as the Modified Kersey method.

The general equation used for calculating the neutron dose equivalent (H_n) at the entrance to the maze is:

$$H_n = W \cdot L_n \cdot \left(\frac{1}{m_1}\right)^2 \cdot (0.1)^{\left(\frac{m_2}{TVD}\right)} \qquad (1)$$

Where:

H_n = Neutron dose equivalent
W = Workload (rad per week or Gy per week)
L_n = Neutron leakage (rem per output photon rad or Sv per output photon Gy)
m_1 = Distance from isocenter to the center of the maze entrance (m)
m_2 = Length of the maze (m)
TVD = Tenth value distance (m)

The neutron dose equivalent (H_n) is used to assess the fast and thermal neutron components at the end of the maze. Each component is about 50% of H_n. These components are separated because they require different shielding materials. Fast neutrons are effectively shielded using hydrogenous materials such as polyethylene, while thermal neutrons are shielded using materials having large thermal capture cross sections, such as boron. The capture gamma component varies from 20% - 50% of H_n. Varian uses the maximum value of 50% since the capture gamma component for a particular facility is usually unknown.

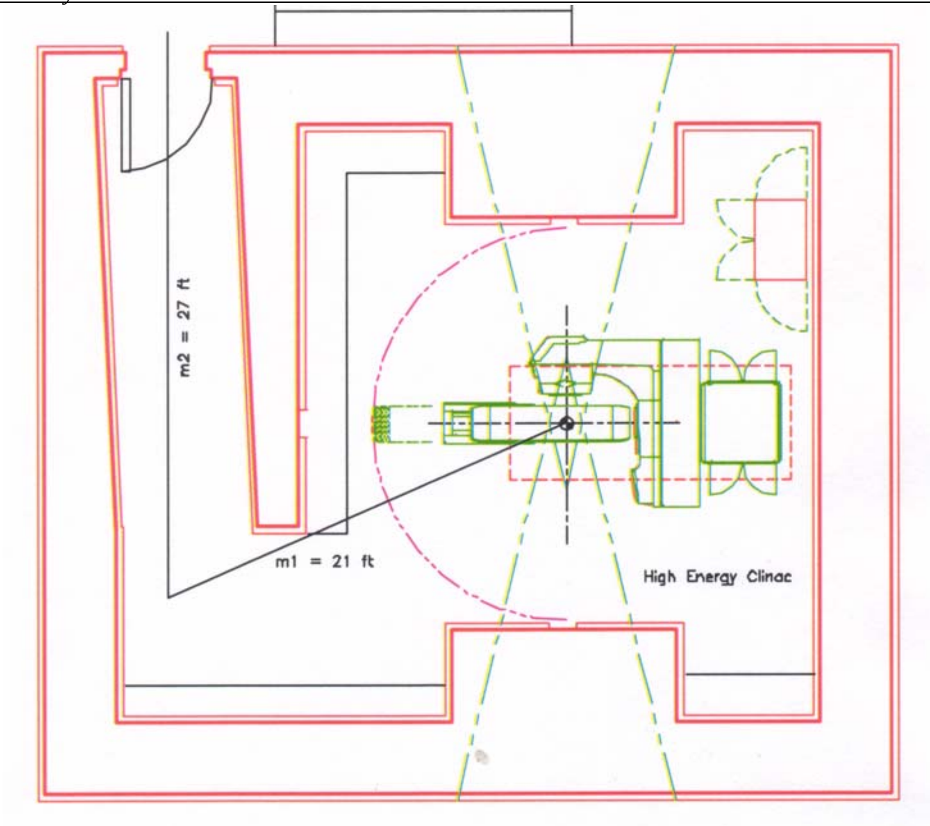

Figure 1 – Sample Treatment Room

As an example, the value of H_n will be calculated assuming:

W = 50,000 rad per week
L_n = 1.5 E-3 (18 MV)
m_1 = 21' (6.4 m)
m_2 = 27' (8.2 m)
P (Permissible limit) = 10 mrem per week

Substituting these values into equation 1, H_n = 16.7 mrem per week. Then, as discussed above, the total estimated dose equivalent at the door is approximately 8.4 mrem per week thermal neutron, 8.4 mrem per week fast neutron and 8.4 mrem per week due to capture gamma, for a total of approximately 25 mrem per week. In this case, a door is required in order to meet the dose equivalent limit (P) of 10 mrem per week. The thermal and fast neutron components are shielded with 5% borated polyethylene. The capture gamma component is shielded with lead. For this example, the door would consist of 3" of 5% borated polyethylene followed by 1.75" of lead surrounded by 0.25" of steel.

The values for L_n are in the high energy Radiation Leakage Report, which can be downloaded at the following URL (document # 12000):

http://www.varian.com/onc/sup204.html#shielding

Note: The values in the leakage report are in percent Gy per output photon Gy.