Depth Dose Measurements
using MOSFETS, diodes and ion chambers

Abstract: *The percent depth dose of 6 and 20 MeV photon beams were measured for various field sizes using three different types of radiation dosimeters: (1) MOSFETs, (2) diodes and (3) ion chambers. All three detectors showed depth dose is a function of photon energy and field size.*

Introduction

Percent depth dose curves are often used in therapeutic radiology. Figure 1 shows a beam of radiation incident on a phantom. The percentage depth dose (P) is the ratio of the dose at X to the dose at Y, both being points within the phantom. It is expressed as:

$$P(d, W_m, F, h\nu)=100\ \frac{D_x}{D_y} \quad (1)$$

The percentage depth dose depends on the depth d, the width of the beam W_m, the distance from the surface of the phantom to the source F, and the beam quality *hv*.

Usually field size is specified at the depth of the reference point, although frequently the surface is often used and W_m in equation 1 becomes W_o.

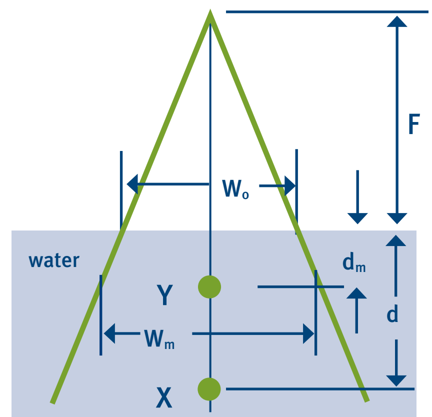

FIGURE. 1. Schematic indicating how percentage depth dose curves are measured

Point Y at depth d_m is the point where the dose D_Y is a maximum while the dose at point X located at any depth d is referred to as D_X. For x-rays generated up to 250 kV_p point Y is on the surface of the phantom while for energies above a few hundred keV the maximum dose is below the surface. For ^{60}Co radiation, which is nearly monoenergetic at an energy of 1.25 MeV, d_m = 0.5 cm, the depth of maximum dose increases with energy, reaching a value of about 5 cm for a continuous spectrum with peak energy 25 MeV.

Dependence of depth dose on depth and photon energy

Figures 2 and 3 show the variation of depth dose with depth for a variety of radiations. Figure 2 shows the variation up to 16 mm while Figure 3 shows it for depths up to 25 cm. In Figure 2 the dose near the surface is examined. With low energy radiation (curve A), the depth dose decreases with depth reaching 80% at 6 mm. The dose from harder radiation (curve B) is almost constant over the depth shown. More energetic radiation, as with ^{60}Co, exhibits an increase in depth dose for the first few mm and then reaches a broad maximum that extends over several mm. As the energy is increased still further the surface dose becomes smaller and the maximum occurs at a greater depth. The reason for this behavior can be explained in terms of electronic buildup. With high energy radiation the electrons are projected primarily in the forward direction. The maximum dose occurs at the point equal to the range of the scattered electron. From this point on, the dose decreases with depth due to attenuation of the photon radiation. The result is that the dose first increases and then decreases.

Depth Dose Dependence on Field Area

For a small field the dose D_X is due entirely to primary radiation since the volume that can scatter is small. As the field size increases, both D_X and D_Y will increase due to scattered radiation. Percentage depth dose increases with area, at first rapidly and then much more slowly as the area is increased.

The variation of percentage depth dose with area depends upon the quality of radiation. This is illustrated in Figure 4 where the 10 cm depth dose is plotted against the radius of the field for low, medium and high energies. The depth dose for zero area is due to primary radiation alone. With large fields the depth dose is due to primary plus scattered radiation. With 25 MeV radiation, scatter is very small, and the depth dose is nearly constant for all field sizes. With ^{60}Co, scatter increases the zero area depth dose from 42% to 60%. It is evident from Figure 4 that high energy radiation offers a big advantage over lower energies especially with small fields.

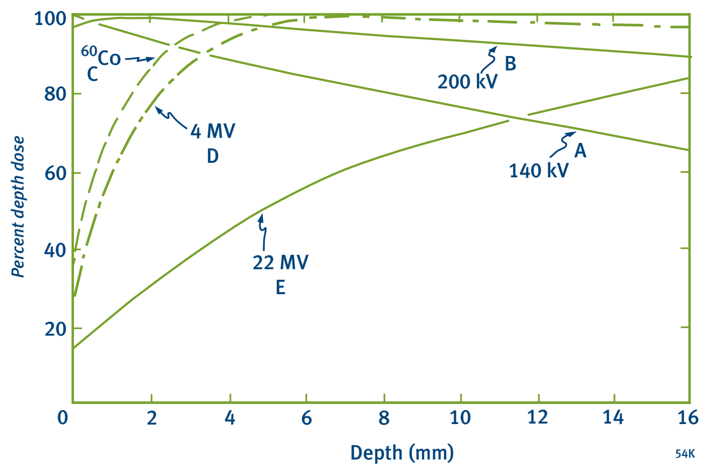

FIGURE. 2. Percentage depth dose as function of depth near the surface for a range of photon beam energies.[1]

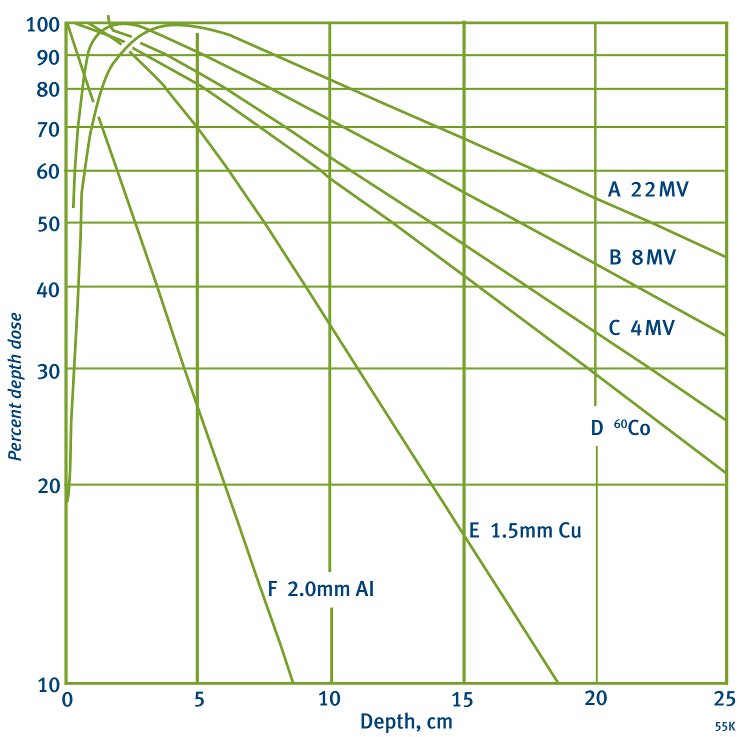

FIGURE. 3. Depth dose variation with up to 25 cm for a variety of energies.[1]

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Figure 5 shows build-up curves for 8 MeV photons for two fields as a function of depth. It is evident that the dose within the phantom increases with field size, with the result being d_{min} has moved closer to the surface.

Comparisons between MOSFET dosimeters, diodes and ion chambers as a function of field size and photon energy are discussed below.

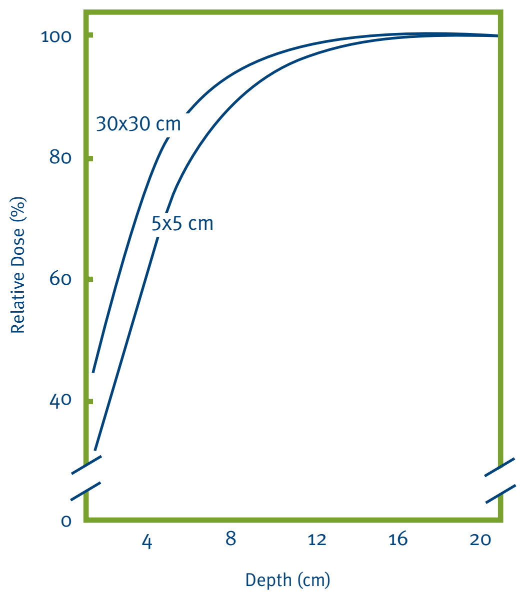

FIGURE 5. Build-up curves for 8 MeV photons for two field sizes as a function of depth.[3]

Field size	diode	ion chamber	MOSFET
10x10cm	1.000	1.000	1.000
20x20cm	1.047	1.056	1.07
40x40cm	1.079	1.108	1.06

TABLE 1. Field measurements for MOSFETs diodes, and Ion Chambers for a 6 MeV photon beam.

Field size	diode	ion chamber	MOSFET
10x10cm	1.000	1.000	1.000
20x20cm	1.058	1.079	1.07
40x40cm	1.097	1.130	1.06

TABLE 2. Field measurements for MOSFETs diodes, and Ion Chambers for a 20 MeV photon beam.

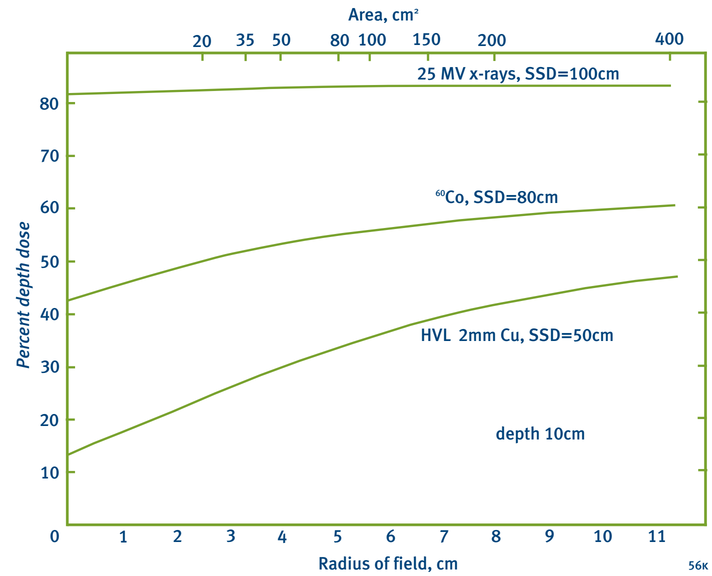

FIGURE 4. Variation of percentage depth dose with radius and area of field for three types of radiation.[2]

Materials and Methods

The diodes used were Nuclear Associates, model 30-494.2 They had integral buildup material for 10 MeV photons. Polystyrene phantom material was used to obtain the percent depth dose curves.

Best Medical Canada MOSFET dosimeters were used in the standard RDS configuration. 2 mm and 4 mm steel caps were used to obtain electron equilibrium at 6 MeV and 20 MeV respectively.

Measurements

Diode measurements were taken within a polystyrene phantom at 2.0 cm for the 6 MeV beam and 3.0 cm for an 20 MeV beam. For Ion chamber measurements, the chamber was situated at 1.5 and 3.0 cm, respectively for 6 and 20 MeV beams.[2] MOSFETs were irradiated with a 6 MeV and 20 MeV beam behind 2 mm of steel and 4 mm of steel respectively. In Tables 1 and 2 three distinct types of dosimeters were used to measure percentage depth dose for various field sizes. It is clear that when electronic equilibrium is maintained dose variation with field size can be minimized.

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MOSFET dosimeters have a very thin (1mm) build-up material covering the detector, making it possible to utilize them to measure entrance dose. This is in contrast to diodes which have thick build-up caps . Figure 6 shows MOSFET dosimeter percentage depth dose curves for 6 MeV and 20 MeV photon beams. The 20 MeV beam at 0 mm is 36% of its total dose, while the 6 MeV beam is at 56%.

Figure 7 shows the variation in depth-dose percentage with field size for shallow depths. It is clear that there is an increase in dose simply by opening the field size.

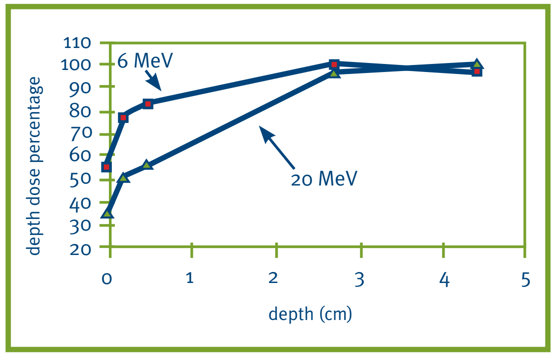

FIGURE 6. 20 MeV and 6 MeV depth dose measurements using MOSFET dosimeters. Note the reduced dose at the shallow depths for the 20 MeV beam.

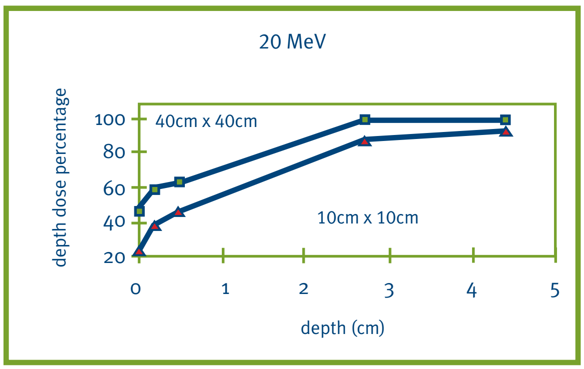

FIGURE 7. Depth dose percentage curves for 10 cm x 10 cm and 40 cm x 40 cm, 20 MeV photon beams.

Figure 7 indicates that electronic equilibrium has not been achieved for the 10 cm x 10 cm field. However, for the 40 cm x 40 cm field electronic equilibrium has been achieved. By increasing the field size to 40 cm x 40 cm, d_m has moved closer to the surface.

Conclusions

Three types of therapeutic radiation dosimeters, MOSFETs, diodes and ion chambers have been used to investigate dose depth percentage curves for various photon energies and field sizes.

When electronic equilibrium is achieved ion chambers, diodes and MOSFETs measure the same dose regardless of field size. This indicates no field size dependence for any of the dosimeters investigated.

A MOSFET has very thin build-up (1mm) on top of its sensitive area, making it very useful in measuring entrance dose. MOSFETs have been used to measure the depth dose percentage curves for shallow and entrance dose for 6 MeV and 20 MeV photon beams. Using MOSFET the reduced surface dose for the more energetic beam can easily be measured. The shift in the build-up curve towards the surface when field size is increased can also be determined from the MOSFET measurements.

References

1. Johns and Cunningham, Physics of Radiology, Charles C. Thomas (publisher), Fourth Edition, 1983.

2. Lee, Sawicka, Glasgow, “Patient Dosimetry Quality Assurance Program With A Commercial Diode System”, Int. J. Rad. Onc. Biol. Phys., Vol 29. No 5. 1989

3. Scanditronix Detectors for patient dosimetery and radiation field analysis