ABC and DEC. From geometry, we have:

$$\frac{DE}{AB} = \frac{CE}{CA} = \frac{CD}{CB} = \frac{MN}{OM} = \frac{OF + FN - OM}{OM} \tag{4.1}$$

If $AB = s$, the source diameter, OM = SDD, the source to diaphragm distance, OF = SSD, the source to surface distance, then from the above equation, the penumbra (DE) at depth d is given by

$$P_d = \frac{s\ (\text{SSD} + d - \text{SDD})}{\text{SDD}} \tag{4.2}$$

The penumbra at the surface can be calculated by substituting $d = 0$ in Equation 4.2.

As the above equation indicates, the penumbra width increases with increase in source diameter, SSD, and depth but decreases with increase in SDD. The geometric penumbra, however, is independent of field size as long as the movement of the diaphragm is in one plane, *i.e.* SDD stays constant with increase in field size.

Since SDD is an important parameter in determining the penumbra width, this distance can be increased by extendable *penumbra trimmers*. These trimmers consist of heavy metal bars to attenuate the beam in the penumbra region, thus "sharpening" the field edges. The penumbra, however, is not eliminated completely but reduced since SDD with the trimmers extended is increased. The new SDD is equal to the source to trimmer distance. An alternative way of reducing the penumbra is to use secondary blocks, placed close to the patient, for redefining or shaping the field. As will be discussed in Chapter 13, the blocks should not be placed closer than 15 to 20 cm from the patient because of excessive electron contaminants produced by the block carrying tray.

The combined effect of the transmission and geometric penumbras is to create a region of dose variation at the field edges. A dose profile of the beam measured across the beam in air at a given distance from the source would show dosimetrically the extent of the penumbra. However, at a depth in the patient the dose variation at the field border is not only a function of geometric and transmission penumbras but also the scattered radiation produced in the patient. Thus, dosimetrically, the term *physical penumbra* width has been defined as the lateral distance between two specified isodose curves[4] at a specified depth (10).

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[4] An isodose curve is a line passing through points of equal dose.

References

1. Paterson R: *The Treatment of Malignant Disease by Radium and X-Rays*. Baltimore, Williams and Wilkins, 1963, p 56.
2. National Council on Radiation Protection: *Medical X-Ray and Gamma Ray Protection for*