Table 4.1.
Teletherapy source characteristics

Radionuclide	Half-life (years)	γ Ray energy (MeV)	Γ Value* $\left(\frac{Rm^2}{Ci - h}\right)$	Specific activity achieved in practice (Ci/g)
Radium-226 (filtered by 0.5 mm Pt)	1622	0.83 (avg.)	0.825	~0.98
Cesium-137	30.0	0.66	0.326	~50
Cobalt-60	5.26	1.17, 1.33	1.30	~200

* Exposure rate constant (Γ) is discussed in Section 8.5. The higher the Γ value, the greater will be the exposure rate or output per curie of the teletherapy source.

(decay scheme given in Fig. 1.5). These γ rays constitute the useful treatment beam. The β particles are absorbed in the cobalt metal and the stainless steel capsules resulting in the emission of bremsstrahlung x-rays and a small amount of characteristic x-rays. However, these x-rays of average energy around 0.1 MeV do not contribute appreciably to the dose in the patient because they are strongly attenuated in the material of the source and the capsule. The other "contaminants" to the treatment beam are the lower energy γ rays produced by the interaction of the primary γ radiation with the source itself, the surrounding capsule, the source housing, and the collimator system. The scattered components of the beam contribute significantly (~10%) to the total intensity of the beam (8). All these secondary interactions thus, to some extent, result in heterogeneity of the beam. In addition, electrons are also produced by these interactions and constitute what is usually referred to as the *electron contamination* of the photon beam.

A typical teletherapy ^{60}Co source is a cylinder of diameter ranging from 1.0 to 2.0 cm and is positioned in the cobalt unit with its circular end facing the patient. The fact that the radiation source is not a point source complicates the beam geometry and gives rise to what is known as the geometric penumbra.

A.2. SOURCE HOUSING

The housing for the source is called the *sourcehead* (Fig. 4.11). It consists of a steel shell filled with lead for shielding purposes and a device for bringing the source in front of an opening in the head from which the useful beam emerges.

Also, a heavy metal alloy sleeve is provided to form an additional primary shield when the source is in the "off" position.

A number of methods have been developed for moving the source from the "off" position to the "on" position. These methods have been discussed in detail by Johns and Cunningham (9). It will suffice here to briefly mention four different mechanisms: (a) the source mounted on a rotating wheel inside the sourcehead to carry the source from the "off" position to the "on" position; (b) the source mounted on a heavy metal plus its ability to slide horizontally through a hole running through the sourcehead. In the "on" position the source

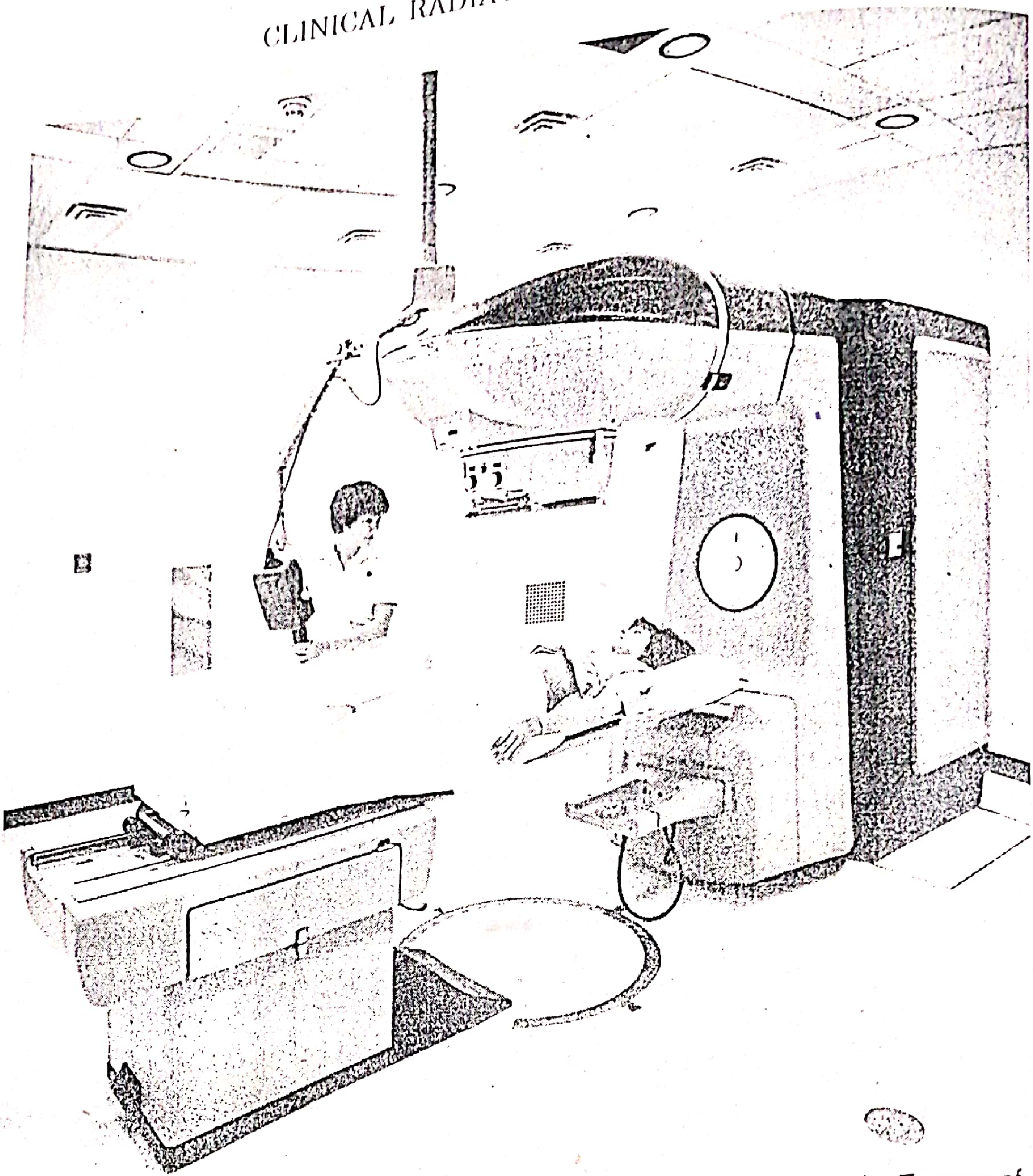


Figure 4.11. Photograph of cobalt unit, Theratron 780. (Courtesy of Atomic Energy of Canada Limited, Ottawa, Canada.)

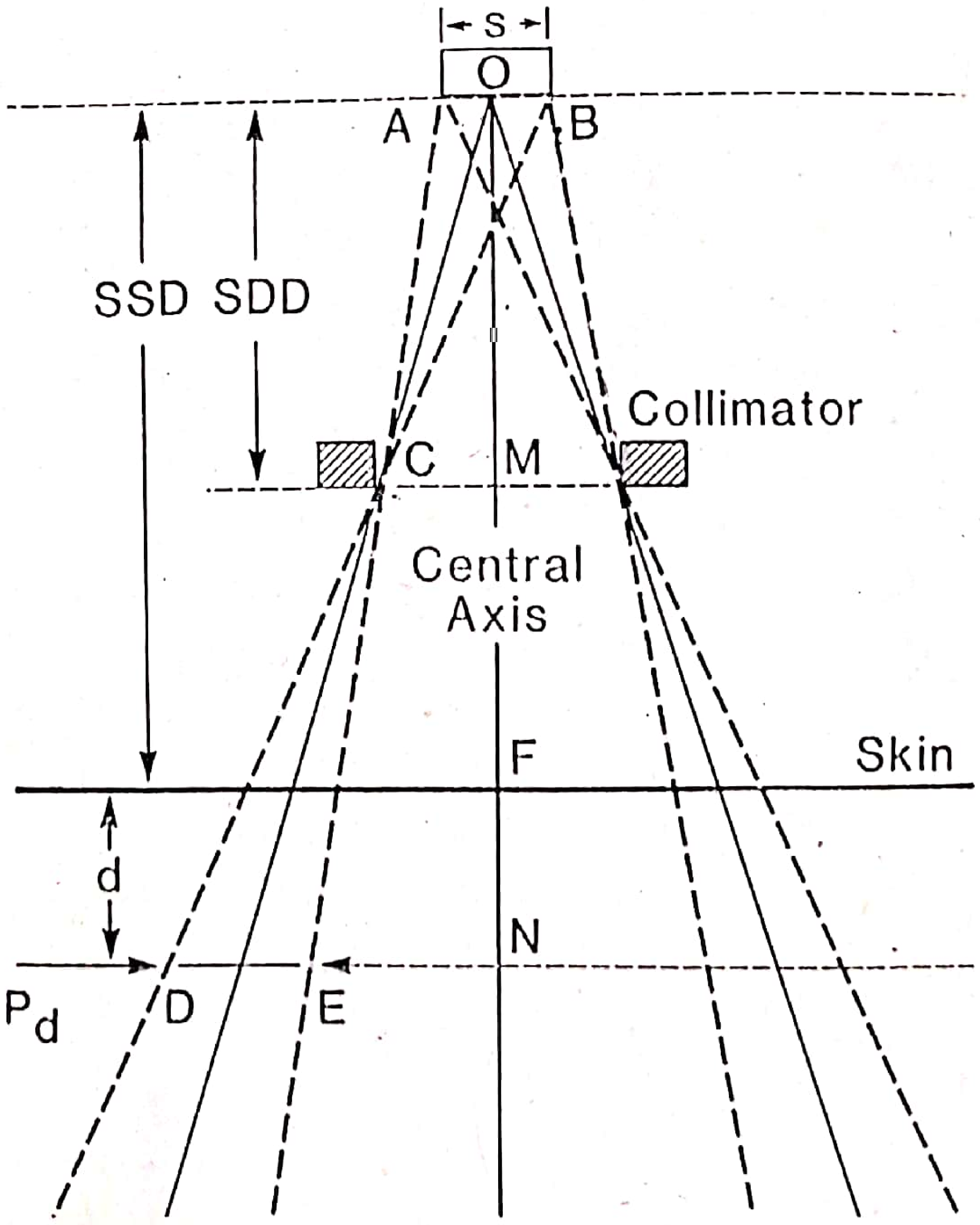
faces the aperture for the treatment beam and in the "off" position the source moves to its shielded location and a light source mounted on the same drawer occupies the "on" position of the source; (c) mercury is allowed to flow into the space immediately below the source to shut off the beam; and (d) the source is fixed in front of the aperture and the beam can be turned on and off by a shutter consisting of heavy metal jaws. All of the above mechanisms incorporate a safety feature in which the source is returned automatically to the "off" position in case of a power failure.

A.3. BEAM COLLIMATION AND PENUMBRA

A collimator system is designed to vary the size and shape of the beam to meet the individual requirements. The simplest form of a continuously adjustable diaphragm consists of two pairs of heavy metal blocks. Each pair can be moved independently to obtain a square or a rectangle-shaped field. Some collimators are multivane type, *i.e.* multiple blocks to control the size of the beam. In either case, if the inner surface of the blocks is made parallel to the central axis of the beam, the radiation will pass through the edges of the collimating blocks resulting in what is known as the "*transmission penumbra.*" The extent of this penumbra will be more pronounced for larger collimator openings because of greater slope ~~obliquity~~ of the rays at the edges of the blocks. This effect has been minimized in some designs by shaping the collimator blocks so that the inner surface of the blocks remains always parallel to the edge of the beam. In these collimators, the blocks are joined hinged to the top of the collimator housing so that the slope of the blocks is coincident with the included angle of the beam. Although the transmission penumbra can be minimized with such an arrangement, it cannot be completely removed for all field sizes.

The term *penumbra*, in a general sense, means the region, at the edge of a radiation beam, over which the dose rate changes rapidly as a function of distance from the beam axis (10). The transmission penumbra, mentioned above, is the region irradiated by photons which are transmitted through the edge of the collimator block.

Another type of penumbra, known as the *geometric penumbra*, is illustrated in Fig. 4.12. The geometric width of the penumbra, P_d, at any depth d from the surface of a patient can be determined by considering similar triangles



ΔABC
ΔDEC

Figure 4.12. Diagram for calculating geometric penumbra.