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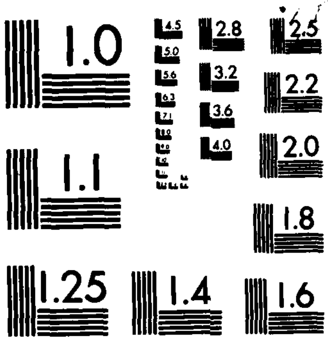

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AFRRI TECHNICAL REPORT

Surface doses in the Cobalt-60 Facility at Armed Forces Radiobiology Research Institute

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Research was conducted according to the principles enunciated in the "Guide for the Care and Use of Laboratory Animals," prepared by the Institute of Laboratory Animal Resources, National Research Council.

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The surface doses in the Cobalt-60 Facility at the Armed Forces Radiobiology Research Institute were measured using a Capentec Model PS-033 0.5 cm^3 parallel plate ionization chamber. With the source in the unilateral mode, the dose in the buildup region (0-5 mm depth) was measured and compared to the equilibrium dose for exposure rates ranging from 5 to 3500 roentgen/minute. It was determined that the usual "skin-sparing" effect of cobalt-60 beams does not exist in the AFRRI Cobalt-60 Facility; in fact, the dose at a

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depth of 1 mm was as high as 137% of the equilibrium dose. The surface dose increased relative to the equilibrium dose as the source was moved closer to the chamber, indicating that the increased skin dose is due to the secondary electrons arising within the cobalt-60 structural components. These dose gradients in the buildup region should be considered when using the Cobalt-60 Facility for experimental irradiations.

CONTENTS

Cobalt-60 gamma radiation is classically regarded as delivering maximum dose (D_{max}) at a tissue depth of 5 mm,* with a "skin-sparing" dose deficit at shallower depths (1). Beyond the buildup region of 0-5 mm, the dose is deposited solely by energetic electrons set in motion within tissue by the gamma rays. In the buildup region, electrons depositing the dose can arise from two other sources, namely, secondary electrons from the air and secondary electrons from the cobalt-60 source mechanism. The amount of such dose depends on the source's physical design and on the source-to-surface distance (SSD). Theratron-80 and other cobalt-60 teletherapy units give surface doses below 50% of D_{max} at normal SSD's of 80-100 cm, but as high as 125% of D_{max} at very short SSD's (2,3). The AFRRI Cobalt-60 Facility (4) is an uncollimated gamma ray source with no provision for control of secondary electrons. The relatively large size of the metallic source mechanism plus the use of SSD's ranging from 27 to 400 cm indicates that secondary electrons from the source mechanism and from the air may make a significant contribution to dose in the buildup region of irradiated objects.

METHODS

Relative dose measurements in the buildup region were made with a Capintec Model PS-033 0.5 cm^3 parallel-plate ionization chamber with a 0.5 mg/cm^2 (3.6 μm) aluminized polyester window. The chamber was centered on the surface of a 30 cm x 30 cm x 5 cm (thick) block of polystyrene for all irradiations, with sheets of plastic overlaid for depth measurements. Ionization currents were measured with a Keithley Model 616 electrometer. Chamber saturation and polarity corrections were less than 2% when operated at ± 500 volts bias in fields as intense as 3500 roentgen (R)/min. Relative dose rates were derived as the ratios of ionization currents at different depths to that at equilibrium depth, with no corrections for variation of electron stopping power or other second-order effects.

Irradiations were done in the unilateral mode at SSD's ranging from 27 to 387 cm. These distances corresponded to exposure rates of approximately 3500 to 50 R/min.

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*Depths in millimeters apply to unit density material. For other materials, scale the depth by the density.

RESULTS

Buildup-region depth-dose curves for the AFRRI Cobalt-60 Facility are shown in Figure 1 together with a sample curve for the AFRRI Theratron-80 unit (from reference 2). Doses as high as 137% of D_{max} were measured in the first 0.1-mm depth at the closest SSD. The surface (0.1-mm depth) dose decreased with increasing SSD, as shown in Figure 2. The data strongly indicate that the cause of the excess surface dose was, indeed, the secondary electrons arising within the cobalt-60 source mechanism. The marked difference between the Cobalt-60 Facility and Theratron-80 depth-dose curves can be attributed to the smaller size of the source plus the positive collimation of the latter.

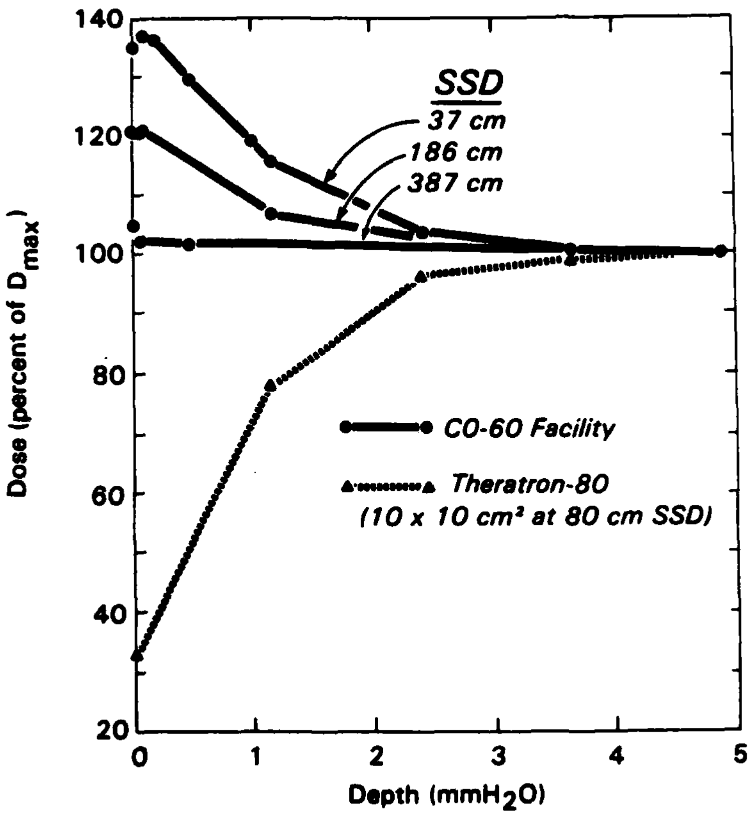

Figure 1. Depth-dose curves in the buildup region

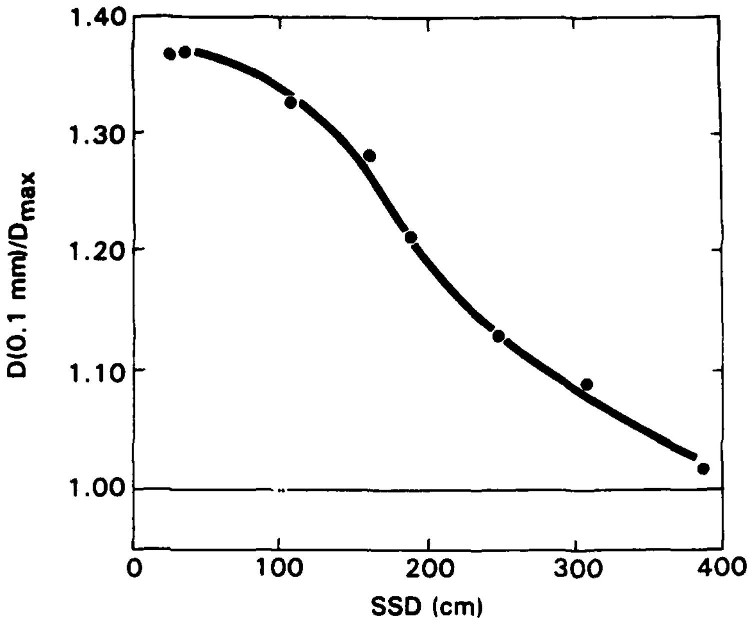

Figure 2. Dose at 0.1 mm relative to D_{max} for different source-to-surface distances (SSD's) in the AFRRI Cobalt-60 Facility

Efforts to reduce the excess surface dose due to source electrons by means of filter materials are summarized in Table 1. A 1/8-inch sheet of lucite positioned between the surface and the source produced nearly uniform depth dose in the buildup region. Copper was reported by others (3) to be the most effective material for filtering of source electrons, and it proved to be useful here as well. The data showed that a 1/16-inch copper sheet actually reduced surface doses to less than D_{max}.

Table 1. Efficacy of Electron Filters for 27-cm SSD Unilateral Irradiations

Filter*	(Dose at 0.1 mm)/ D_{max}
None	1.37
3.18 mm acrylic	
15 cm from surface	1.09
5 cm from surface	1.02
1.59 mm copper	
10 cm from surface	0.89

*Acrylic and copper filters were approximately 30 cm x 40 cm in size.

DISCUSSION

The AFRRI Cobalt-60 Facility has been found to have significant electron contamination that produces severe dose gradients in the buildup region of irradiated objects. Doses as high as 137% of the equilibrium dose were found at depths of less than 1 mm for unilateral* irradiations at the shortest SSD. At no SSD was a skin-sparing effect observed in the AFRRI Cobalt-60 Facility; all measured surface doses were greater than or equal to the equilibrium dose. These findings stand in sharp contrast to the classical picture of cobalt-60 dose deposition near the surface of irradiated objects.

Cobalt-60 Facility buildup-region depth-dose curves indicate the influence of secondary electrons from both the source mechanism and the air. To interpret these curves, one must recall that the maximum range in air of cobalt-60 secondary electrons is about 350 cm. For SSD's beyond 350 cm, no source-electrons can reach the

*For bilateral irradiations, dose gradients in the buildup region will be less severe, due to the dose contribution from the exiting beam.

surface, but the air provides an equilibrium electron fluence. While many air-electrons scatter away from the surface, the uncollimated beam allows other electrons to scatter into the direction of interest. This explains the uniform depth dose through the buildup region for very large SSD's. For SSD's shorter than 350 cm, the air no longer provides an equilibrium electron fluence, but secondary electrons from the source mechanism can reach the surface. The higher surface doses at shorter SSD's show that the increasing fluence of source-electrons more than offsets the decreasing fluence of air-electrons.

A 1/16-inch sheet of copper was found to be effective in filtering secondary electrons arising in the source mechanism. Leung and Johns (3) found that copper was more effective as an electron filter than were lucite, lead, aluminum, glass, iron, or film. Thus, suitably designed permanent copper filter devices for the AFRRI Cobalt-60 Facility sources would allow irradiations with reduced electron contamination.

Most experimental irradiations in the AFRRI Cobalt-60 Facility use an equilibrium thickness of material, such as 1/8-inch acrylic, around the irradiated object, e.g., a cage, test tube holder, or dosimeter equilibrium cap. The surface dose gradients described above do not affect such irradiations because secondary electrons from the cobalt-60 source cannot penetrate beyond an equilibrium thickness. However, in cases in which the surface of an irradiated object is exposed directly to the radiation field (e.g., skin of experimental animal) or in which container walls are thinner than 3.5 mm (e.g., in vitro work in thin plastic tubes or plates), due regard must be given to dose gradients in the buildup region.

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