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AFRRI COLBALT WHOLE-BODY IRRADIATOR

Robert E. Carter, et al

Armed Forces Radiobiology Research Institute
Bethesda, Maryland

March 1973

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R. E. Carter and D. M. Verrelli

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13. ABSTRACT

The AFRRI cobalt irradiator contains two sets of sources, allowing for either unilateral or simultaneous bilateral irradiation of large animals or objects. With a loading of 25 kCi of ^{60}Co, exposure rates up to 400 R/minute are possible. The exposure rate can be varied either by changing the number of source rods or by changing the source to target distance. A brief description of the facility and the results of its calibration are presented.

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AFRRI COBALT WHOLE-BODY IRRADIATOR

R. E. CARTER
D. M. VERRELLI

Robert E. Carter

R. E. CARTER
Chairman
Physical Sciences Department

Myron I. Varon

MYRON I. VARON
Captain MC USN
Director

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
Defense Nuclear Agency
Bethesda, Maryland

Approved for public release; distribution unlimited

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ABSTRACT

The AFRRI cobalt irradiator contains two sets of sources, allowing for either unilateral or simultaneous bilateral irradiation of large animals or objects. With a loading of 25 kCi of ^{60}Co, exposure rates up to 400 R/minute are possible. The exposure rate can be varied either by changing the number of source rods or by changing the source to target distance. A brief description of the facility and the results of its calibration are presented.

I. INTRODUCTION

The Armed Forces Radiobiology Research Institute cobalt-60 irradiator, completed in December 1970, provides an in-house capability for the study of gamma radiation effects on large animals or objects.

The facility was designed to AFRRI specifications by the National Bureau of Standards. The key features of the facility include the ability to provide (1) a wide range of exposure rates up to approximately 400 R/minute and (2) a large exposure volume within which the exposure rate is uniform.

The purpose of this report is to provide a brief description of the facility and the results of its calibration.

II. DESCRIPTION OF THE FACILITY

The AFRRI cobalt-60 gamma irradiation facility (Figure 1) is a 35-foot square room with an internal height of 25 feet 8 inches. It is located below ground on the south side of the AFRRI complex. The combination of concrete and earthfill will provide sufficient shielding for 500,000 Ci of cobalt-60. The present loading of the cobalt facility is approximately 25,000 Ci (March 1973).

In the center of the exposure room floor is a water-filled pool, 16 feet deep and 6 feet in diameter; extending from this central pool to the midpoints of the north and south walls are two trenches, 30 inches wide and 16 feet deep. With the sources at the bottom, the 16-foot depth provides sufficient water shielding to reduce radiation levels in the room to safe limits for personnel occupancy.

The cobalt sources are cylindrical rods doubly encapsulated with aluminum and stainless steel. There are 30 rods, each of which is 10-1/2 inches long and 1 inch in diameter, and each has an activity of about 1000 Ci.

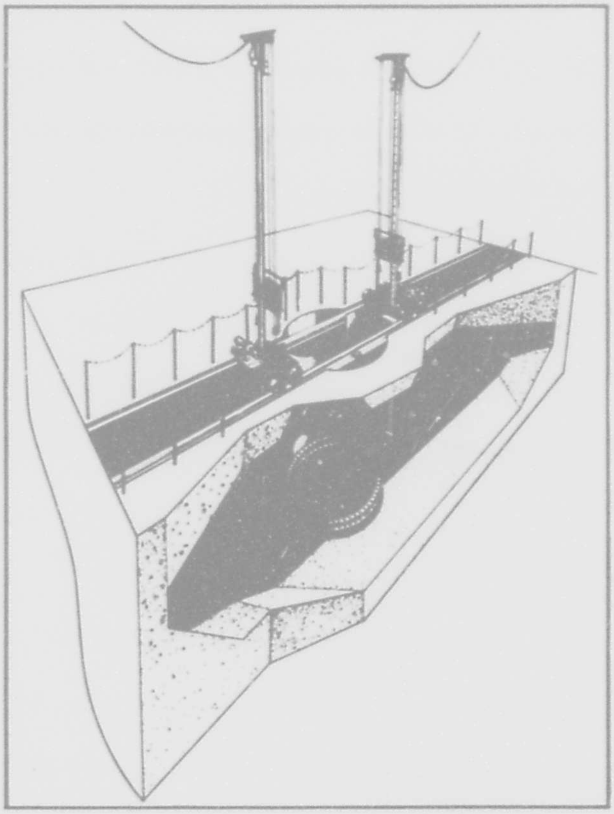

Figure 1. AFRRI cobalt-60 irradiator

The two elevator carriages can be manually positioned at any point along the trench. A column extends vertically from each carriage, permitting a source array cage to be raised from the pool bottom to any height up to 12-1/2 feet above floor level (midway between floor and ceiling). The vertical movement is accomplished by remote control. The vertical positioning is reproducible within 0.5 inch.

Either source cage (see Figure 2) can accommodate up to 15 rods; thus the exposure rate can be controlled by source strength as well as source to target distance.

The two elevators are capable of independent or simultaneous operation. The sources can be raised from 18 inches below water level to the top of the column in less than 60 seconds. Total elevation time from the bottom of the pool is less than 120 seconds. The vertical position is selected remotely at the control console.

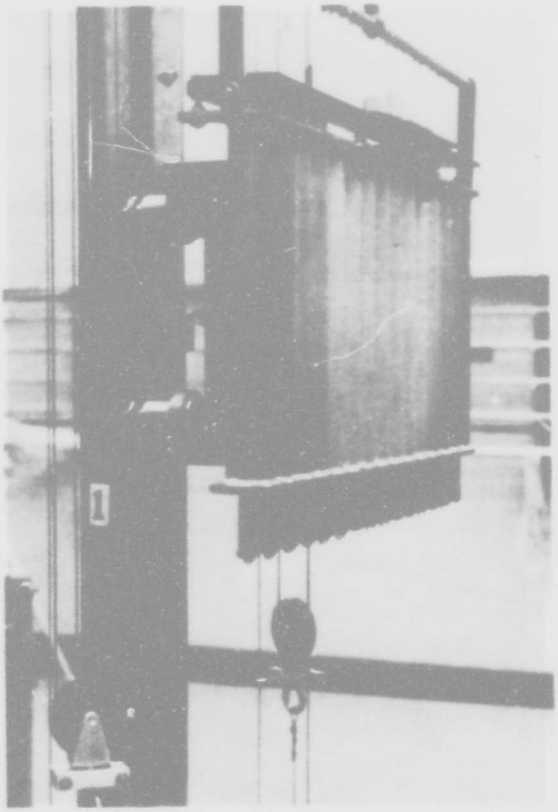

Figure 2. Source cage array

III. FACILITY CALIBRATION

Exposure rates and total exposures were measured using the AFRRI transfer standard, a 3 cm^3 air-equivalent ionization chamber.[1]

<u>Exposure rates</u>. The exposure rate at 12-1/2 feet above the floor of the exposure room was measured for a loading of 30 rods (15 in each elevator cage) and at a number of source(s) to target distances. A least squares fit of the data to a simple power function, $\dot{X} = \dot{X}_0 d^{-x}$, gave a slope of -1.946. Normalized to the exposure rate

at 1 meter, these data indicate a scatter component of < 8 percent at a source to specimen distance of 4 meters.

To accommodate large animal irradiations, a portable, general purpose irradiation table is positioned over the 6-foot diameter tank, as illustrated in Figure 3. Exposure rates for a number of source positions were remeasured. A least squares fit of these data (see Figure 4) gave a slope of -1.925. By comparison with the exposure rate data at 12-1/2 feet, it is determined that the scatter component at 5-1/2 feet above the floor is increased less than 3 percent.

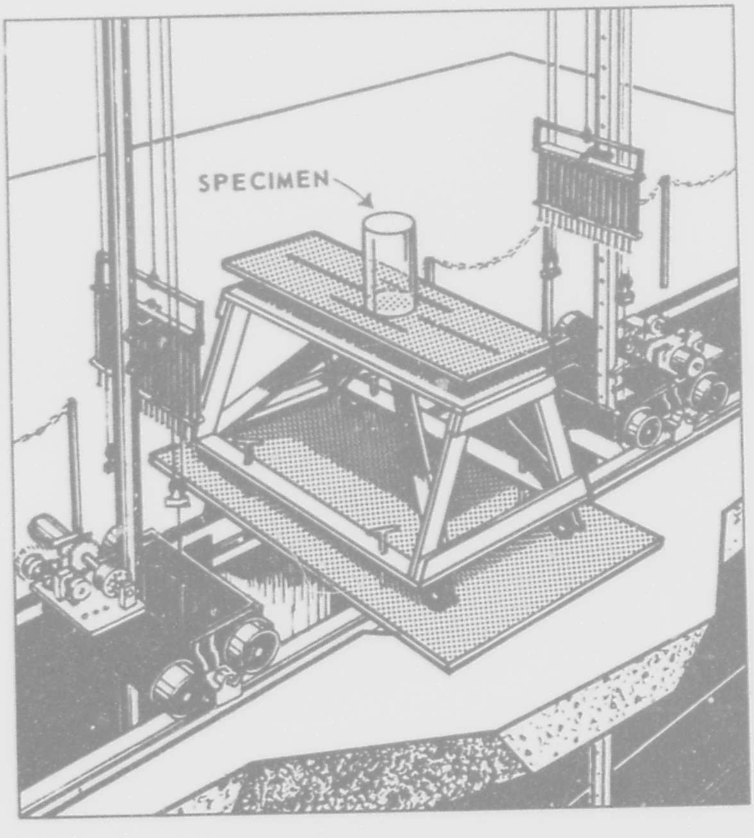

Figure 3. Irradiation geometry for cobalt-60 facility

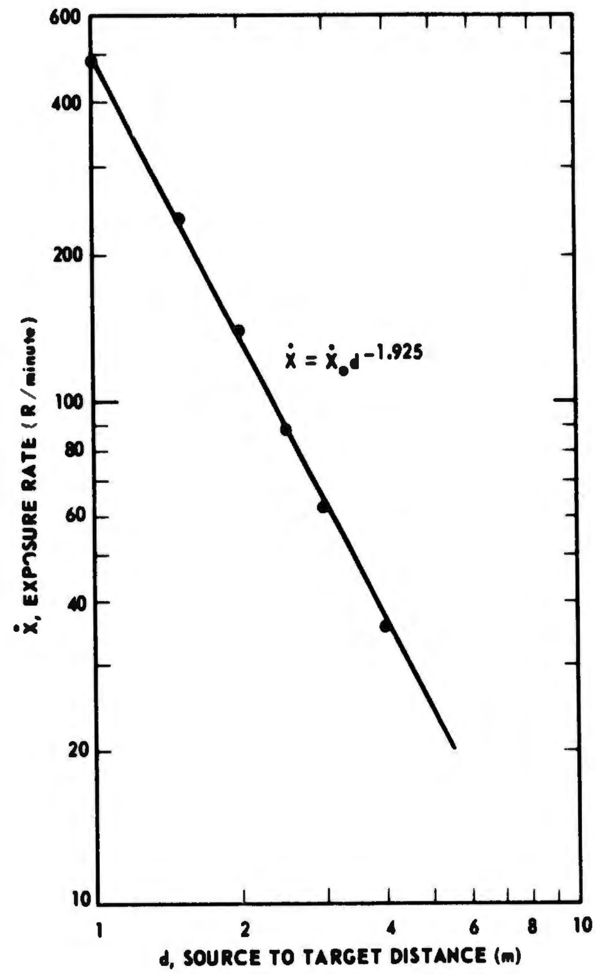

Figure 4. Cobalt irradiator exposure capability

Constant exposure. All experiments will receive a "constant exposure" during the movement of the sources up to their irradiation positions. An additional constant exposure will occur as the sources are lowered into their underwater storage position. For short irradiation times, this constant exposure can be an appreciable fraction of the total exposure. For ease of calculations, it is assumed that the exposure during elevation of the sources is equal to the exposure while lowering them. In addition, it is assumed that the sources are idealized point sources, that there is no attenuation of the primary photon flux, and that the scatter component is a constant fraction of the exposure rate. The exposure rate during this transient period can be expressed as:

$$\dot{X}(r,t) = \frac{\dot{X}_o d_o^2}{r^2} = \frac{\dot{X}_o d_o^2}{\dot{y}} \quad \frac{\dot{r}}{r(r^2 - d_o^2)^{1/2}} \tag{1}$$

where $\dot{X}_o$ is the exposure rate at a source distance of d_o; $\dot{y}$ is the vertical speed of the source. The speed of the elevators was measured to be 300 cm/min. The constant exposure for elevation of the sources, X_c, is obtained by integration of equation (1). This integration yields

$$X_c = \frac{-X_o d_o^2}{300} \frac{1}{d_o} \cos^{-1}\left(\frac{d_o}{r}\right) \Bigg|_{r = (y_o^2 + d_o^2)^{1/2}}^{r = d_o} \quad . \tag{2}$$

If it is assumed that the constant exposure is delivered over 190 cm of vertical travel (from approximately 7-1/2 inches below water level), equation (2) can be evaluated as a function of source to target distance. A comparison of calculated and measured constant exposures is shown in Table I. For purposes of calculation, measured values of $\dot{X}_o$ were used. The measured values for constant exposure were obtained by integration of ion chamber current over the full length of travel of the elevators from the bottom of the pool to the 5-foot position above the floor.

STD*	$2X_c$ (rads) Full loading	
	Calculated	Measured
150	212	213
200	137	136
250	95	94
300	70	69
400	42	40

* Source to target distance in centimeters

Table I. Constant Exposures for Bilateral Irradiations

IV. DOSIMETRY

The types of experiments which use the cobalt facility are whole-body exposures, normally performed in the bilateral mode. For such exposures, the absorbed dose at the midline of the specimen is usually reported. In cases of a uniform irradiation (Class A),[2] the dose is expressed as a single number. For nonuniform irradiation (Class B),[2] a depth-dose distribution through the specimen is provided.

Published depth-dose data are based primarily on measurements made with a homogeneous phantom, usually water, and are referred to 100 percent at the maximum as a function of depth. Because of the variety of specimens irradiated, the geometric configurations employed, and the undesirability of using restraining devices for certain irradiations, bolus is not employed. Under these conditions it is difficult to convert radiation exposure directly to absorbed dose for a given irradiation. This difficulty arises at depths less than the maximum range of electrons produced by absorption of the photons; at such depths, the electron fluence and therefore the absorbed dose is comprised of electrons generated within the specimen and accompanying the incident photons. In addition, these data must be corrected for differences in composition through the specimen (layers of bone, fat, air cavities, etc.). Generally, dosimetry at AFRRI is accomplished by performing depth-dose measurements for each geometrical configuration. Animal cadavers or geometrically similar phantoms are used for these measurements. Dosimetry is performed with miniature ionization chambers and LiF thermoluminescent detectors.

REFERENCES

1. Attix, F. H., Roesch, W. C. and Tochilin, E., editors. Radiation Dosimetry, 2nd ed., Vol. II. New York and London, Academic Press, 1966.

2. International Commission on Radiological Units and Measurements (ICRU) Report 10e, 1962. Radiobiological dosimetry. National Bureau of Standards Handbook No. 88. Washington, D. C., U. S. Government Printing Office, 1963.