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on

DESIGN STUDIES ON CESIUM-137 AS A SOURCE FOR HIGH LEVEL GAMMA IRRADIATORS

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Attn: Steven V. White, Director
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I. INTRODUCTION

In studies on the design of high level Cs^{137} gamma irradiators, the work during this second quarter has continued to be mainly concerned with analytical studies of the influence of source parameters on irradiator performance, and with preparations for radiation field mapping with low level experimental sources of varying dimensions.

A more systematic analysis has been made of the expected behavior of infinite plane sources for irradiating water equivalent slab absorbers; and the limitations imposed on irradiator efficiency, dose rate and dose uniformity due to finite plaque source dimensions.

The main experimental sources designed to test the validity of this analysis consist of a set of thin brass trays filled with Cs^{137} in aqueous solution. Further work has also been done on tests and calibrations of the small scintillator probes for radiation field mapping in water absorbers.

II. ANALYTICAL STUDIES

Since the economic attractiveness of Cs^{137} for high level gamma irradiators depends primarily on the source costs and irradiator efficiency, the design studies we have been concerned with are oriented towards those source parameters which favor high efficiency together with low fabrication and operating costs for the irradiator. Plaque sources for the irradiation of rectangular slab absorbers are being considered in detail, with some consideration also being given to simpler irradiator geometries, such as those encountered with point and line sources for the irradiation of fluid materials.

As indicated in our previous report, ARF 1150-3, the method of design analysis used here for plaque sources makes use of theoretical relations governing the uncollided and scattered radiation flux due to infinite plane isotropic sources. The effects of source thickness and cladding are included by a transformation from slab to equivalent plane source. Reductions in dose rate and efficiency due to finite dimensions of source and absorber are then treated in terms of correction factors which are applied to the infinite geometry results.

For the infinite plaque sources, a consistent set of new computations has been made, covering the photon energy range from 0.4 to 3 Mev. This includes Ir^{192}, Co^{60}, Na^{24}, as well as the Cs^{137} source material of primary interest in this study. A simplifying feature which emerges is that one inch of water equivalent absorber is indicated as the required source assembly thickness for removing the steep field gradient near the source at all of the photon energies considered. Further, by selecting the source cladding to be 1/16 inch of stainless steel, this condition leads to recommended source thicknesses up to ~ 3 gm/cm^2 for all the gamma sources considered. In the case of Cs^{137}, this suggests the use of up to 1 cm thickness of compressed cesium chloride source material, in agreement with our previous estimate.

Table I lists the values expected on this basis for the geometry factor $\overline{G'}$ at half depth in 6 inch water absorber, the depth dose uniformity U and fractional irradiator efficiency F for infinite plaque sources and several absorber configurations. It may be seen that in these results the geometry factor $\overline{G'}$ and U are nearly independent of photon energy, and that irradiator

TABLE I

APPROXIMATE BEHAVIOR OF INFINITE PLAQUE GAMMA IRRADIATORS FOR 6 INCH THICK WATER SLAB ABSORBERS

(Source assembly thickness (b'_s) chosen equal to 1 inch water equivalent for uncollided source photons)

Gamma Energy	E_o - Mev	0.40	0.66	1.25	2.76
One pass on either side of source	$\overline{G'}$	1.19	1.03	1.02	1.16
	U	1.16	1.25	1.24	1.22
	F	0.60	0.52	0.46	0.37
Two passes on either side of source	$\overline{G'}$	1.42	1.34	1.41	1.76
	U	1.20	1.23	1.20	1.20
	F	0.71	0.67	0.64	0.56

Based on:

$$\overline{G'}(b') = E_1(b') \left[1 + 2(\sigma_s/\mu_a)b'\right] ; \overline{G'} = G'(t/2)$$

$$U = \left[G'(o) + G'(t)\right]/2\, G'(t/2)$$

$$F = \mu_a t \overline{G'}$$

efficiencies F in the region of 60 per cent are to be expected before corrections are applied for finite irradiator dimensions.

Table II shows derived values for two of the principal correction factors, corresponding to the case of long plaque sources, small air gaps and variable source heights H_s. The factor $\overline{K}$ denotes the fractional reduction in dose rate at half depth, and the factor H_t/H_s is the reduction in efficiency when using source overlap for dose uniformity in the vertical direction.

III. EXPERIMENTAL PROGRAM

A. Low Level Sources

The design of low level sources settled on for initial experiments consists of the use of thin (1/16 inch wall thickness) brass trays, with dimensions 20 inches x 20 inches x 1/2 inch thick, each filled with approximately 1 millicurie of Cs^{137} in aqueous solution. The following source parameters then pertain:

a) Source thickness $h \sim 1.25$ gm/cm^2; $\mu_s h \sim 0.10$;

$b_c \sim 0.10$; and $b'_s \simeq 0.15$.

b) H_s and L_s values for the source height and length can be varied over the region of 20 inches to 80 inches i.e., $\overline{\mu} H_s \sim 4.3$ to 17.

c) Dose rates: D in the region 20 to 1 mr/hr, going from the surface of the source to 12 inches depth in water.

A trial source of this type has been assembled and initial field measurements in air indicate that the method will be satisfactory. A set of four identical trays is now under construction, with additional spaces inside

TABLE II

APPROXIMATE DEPTH DOSE AND EDGE EFFECT CORRECTION FACTORS FOR LONG PLAQUE SOURCES OF HEIGHT H_s

	E_o - Mev	0.40	0.66	1.25	2.76
	$1/\bar{\mu}$ - inches H_2O	3.6	4.6	6.25	9.6
H_s = 72 inches	$\overline{K}$	0.95	0.93	0.91	0.87
	H_t/H_s	0.90	0.87	0.83	0.73
H_s = 48 inches	$\overline{K}$	0.92	0.90	0.87	0.80
	H_t/H_s	0.85	0.81	0.74	0.60
H_s = 24 inches	$\overline{K}$	0.85	0.81	0.74	0.60
	H_t/H_s	0.70	0.62	0.48	0.20

Based on:

$\overline{K} \sim 1 - 1/\bar{\mu} H_s$ when $\bar{\mu} L_s >> 1$; $\bar{\mu} g << 1$

$H_s \sim H_t + 2/\bar{\mu}$

the trays to keep their surfaces closely parallel.

For the preparation of high level Cs^{137} sources with suitably small thickness (up to one with water equivalent for source plus cladding, or source thickness h up to $\cong$ 1 cm of compressed cesium chloride source material), our preliminary tests show promising results for the rolling of preformed simple source containers into flat sections. An independent program is also under development at ORNL for the direct pressing of CsCl powder into thin rectangular wafers.

B. Radiation Field Mapping

The objective here is to obtain measurements of the absorbed dose rate distribution D in water absorbers by means of the phototube currents produced in an anthracene scintillator probe. From the observed current readings, which respond to the absorbed dose rate in anthracene, we want to deduce the absorbed dose rate D in water. For comparison with the theoretical values shown in Tables I and II, experimental distributions will be made for G', $\overline{G'}$ from the asymptotic behavior with varying source dimensions, and correction factors, K, $\overline{K}$ for specific irradiator configurations.

Initial calibration tests have been made in air, using a very thin crystal (5 mm), 4 inch lucite light pipe and 3/4 inch diameter 10 stage Dumont phototube. Before starting dose measurements in water, further studies will be made for improved sensitivity and reduction of noticeable time variations in the background current.

It has been assumed in the analytical studies that the buildup factor for scattered radiation is a function only of absorber depth. To test this, and other features, the photon spectra will also be examined in water by means of a sodium scintillator probe and pulse height analyzer. Initial tests with a small probe have shown satisfactory resolution of the Cs^{137} photo-peak for a point source in air. However, further work is required in order to remove instrumental fluctuations which masked the lower energy end of the spectrum.

IV. CONCLUSIONS

Further studies have been made on the analytical behavior and experimental testing of Cs^{137} plaque irradiator designs. The conditions selected for study show promise for application to high level Cs^{137} gamma irradiators possessing high utilization efficiency and good dose uniformity.

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology

L. Voyvodic

L. Voyvodic,
Senior Physicist
Nuclear Physics Section

C. A. Stone

C. A. Stone, Supervisor
Nuclear Physics Section

APPROVED:

J. Brophy / for

J. Reiffel
Director of Physics Research