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**CALCULATED THICKNESS OF TUNGSTEN ALLOY REQUIRED FOR
SPECIFIED ATTENUATION OF GAMMA RADIATION FROM ^{137}CS ***

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Calculated Thickness of Tungsten Alloy Required for Specified Attenuation of Gamma Radiation from $^{137}\text{Cs}^1$

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Abstract

The traditional method of evaluating and calibrating health physics instruments is to use a calibrator that consists of a single high-activity gamma radiation source with different attenuators to select the radiation level desired for testing. To have accurate radiation intensities inside the calibrator cavity, the attenuators must be designed from precise absorption calculations. This paper reports calculations made to determine the thickness of tungsten alloy metal required for specific attenuation. These calculations include the buildup contribution by secondary scattering radiation, and they are compared to values calculated with the buildup factor omitted.

I. INTRODUCTION

Radiation survey instruments used by health physicists to monitor radiation exposure of personnel must be calibrated to accurately measure the intensity of radiation present. A calibrator (conceptual design in Fig. 1) is required to evaluate and calibrate these instruments at specific radiation intensities. The traditional method of doing this is to use a single high-activity gamma radiation source with different selectable thicknesses of electromagnetic radiation absorbers to accurately attenuate the radiation to the level of activity desired. To have accurate radiation levels of activity in the measurement cavity of the calibrator, the attenuators must be designed from precise absorption calculations and fabricated to very close tolerances.

II. MATERIALS FOR ABSORBERS

Tungsten metal has a high electromagnetic absorption coefficient and high density, which makes it desirable for gamma-ray attenuators. Pure tungsten is very difficult to machine, but a commercially available alloy of tungsten with a density of 17.0 gm/cm^3 is a very good material from which

to fabricate gamma attenuators. The alloy selected for our design has a chemical composition of 90% W, 6% Ni, and 4% Cu.

III. CALCULATIONS AND PLOTTED DATA

A one-dimensional radiation transport code was used to calculate kerma (kinetic energy released in matter: the sum of the initial energies of all charged particles released per unit mass of material from interactions of indirectly ionizing radiation—primarily neutrons and photons) ratio values from cesium-137 vs absorber thickness. These calculations included the buildup factor contributed by the secondary radiation scattering that occurs in the absorption media, which must be taken into account. Some calculated kerma values (exiting/entering ratios) for different thicknesses of absorber are shown in Table 1 and Fig. 2. To emphasize the buildup contribution, kerma values omitting the buildup factor are also plotted for comparison.

Table 1. ^{137}Cs gamma-ray current-kerma ratio (exiting/entering) for a W-Ni-Cu absorber of 17.00 g/cc

Absorber thickness (cm)	Kerma ratio
1	2.16×10^{-1}
2	4.15×10^{-2}
4	1.40×10^{-3}
6	4.44×10^{-5}
8	1.36×10^{-6}
10	4.09×10^{-8}
12	1.21×10^{-9}
14	3.58×10^{-11}

Although the instruments in the facility would measure in units of roentgen (R), only the air kerma was actually calculated by the transport code: air kerma can be converted to roentgen by simply knowing the work function for the materials; however, because the ratios of exiting-to-entering current kermas were calculated, the work function would simply cancel. The air kerma was calculated by using

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Fig. 1. Conceptual design of a calibrator.

Fig. 2. Kerma ratio vs attenuator thickness, cesium-137 gamma source.

kerma values from the DABL69 (reference 1) cross-section library for N₂, O₂, and Ar (calcium was substituted for argon, which was not available). Table 2 shows the weight fractions used to determine the air kerma.

Table 2. Air kerma factor weight fractions

Element	Weight fraction
Nitrogen	0.755
Oxygen	0.231
Calcium ^a	0.013

^aCalcium kerma factors were substituted for argon, which was not available.

The P5 (Legendre expansion) transport cross sections for W, Ni, and Cu, which made up the tungsten-alloy attenuators, were taken from the DABL cross-section library.

Because the maximum angle the source makes with the attenuator is small and the calculations were to be one dimensional, the source was input in the most forward direction of the Gaussian angular quadrature (Table 3). Cesium-137 is in equilibrium with barium-137, which is the isotope that actually emits a photon with an energy of 0.662 MeV (reference 2).

Calculations were made with attenuator thicknesses of 1, 2, 4, 6, 8, 10, 12, and 14 cm. The transport cross sections, the cesium gamma source, and the geometry were input to the ANISN³ code; and the problems were then run on the CRAY computer.

IV. CONCLUSIONS

Because of the use of the one-dimensional analysis, material density variations, and the uncertainty associated with the interaction cross sections, the uncertainties on the ratios are considered good to within $\pm 10\%$ with a 95% confidence limit.

V. REFERENCES

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Table 3. S40 Gaussian quadrature constants

Angle number	Cosine of angle	Weight
1	-1.0000	0.0000
2	-9.9824×10^{-1}	2.2606×10^{-3}
3	-9.9073×10^{-1}	5.2491×10^{-3}
4	-9.7726×10^{-1}	8.2105×10^{-3}
5	-9.5792×10^{-1}	1.1123×10^{-2}
6	-9.3281×10^{-1}	1.3969×10^{-2}
7	-9.0210×10^{-1}	1.6730×10^{-2}
8	-8.6596×10^{-1}	1.9391×10^{-2}
9	-8.2461×10^{-1}	2.1935×10^{-2}
10	-7.7831×10^{-1}	2.4348×10^{-2}
11	-7.2732×10^{-1}	2.6614×10^{-2}
12	-6.7196×10^{-1}	2.8720×10^{-2}
13	-6.1255×10^{-1}	3.0653×10^{-2}
14	-5.4947×10^{-1}	3.2402×10^{-2}
15	-4.8308×10^{-1}	3.3956×10^{-2}
16	-4.1378×10^{-1}	3.5306×10^{-2}
17	-3.4199×10^{-1}	3.6443×10^{-2}
18	-2.6815×10^{-1}	3.7362×10^{-2}
19	-1.9270×10^{-1}	3.8055×10^{-2}
20	-1.1508×10^{-1}	3.8520×10^{-2}
21	-3.8772×10^{-2}	3.8753×10^{-2}
22	3.8772×10^{-2}	3.8753×10^{-2}
23	1.1508×10^{-1}	3.8520×10^{-2}
24	1.9270×10^{-1}	3.8055×10^{-2}
25	2.6815×10^{-1}	3.7362×10^{-2}
26	3.4199×10^{-1}	3.6443×10^{-2}
27	4.1378×10^{-1}	3.5306×10^{-2}
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36	9.0210×10^{-1}	1.6730×10^{-2}
37	9.3281×10^{-1}	1.3969×10^{-2}
38	9.5792×10^{-1}	1.1128×10^{-2}
39	9.7726×10^{-1}	8.2105×10^{-3}
40	9.9073×10^{-1}	5.2491×10^{-3}
41	9.9824×10^{-1}	2.2606×10^{-3}

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