RADIATION PROTECTION FOR SAFE HANDLING
OF \(^{252}\)Cf SOURCES*

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Californium-252 may be used extensively as a new source of neutrons in the next few years.\(^{(1)}\) Because of the high emission rate $[2.4 \times 10^{12}$ neutrons/(sec)(gram)] from spontaneous fission,\(^{(2)}\) californium can be fabricated into useful sources that are physically small -- one of its major attractions. The first sources were fabricated at this laboratory in the configuration of radium therapy needles.\(^{(3)}\) Because the users of these sources may be radiologists and medical personnel unfamiliar with neutron hazards, some of the characteristics of $^{252}$Cf sources should be reviewed from a health physics viewpoint.

The neutron and gamma ray dose-equivalent rates from a microgram of $^{252}$Cf in air are shown in Fig. 1. These relations were extrapolated by the inverse-square relation from Stoddard's\(^{(2)}\) calculations of neutron and gamma ray dose rates at one meter and were verified by actual measurements with a polyethylene ball neutron dosimeter and \(^7\)LiF thermoluminescent dosimeters over the distances shown. The dose rate due to one milligram of radium is also shown for comparison.

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The greater dose rate from californium may be puzzling to the radiologist who has been told that a microgram of californium is about equal to a milligram of radium for therapeutic use. The difference is due to the quality factor used for radiation protection purposes, which is 3.3 times greater than that used in the therapy calculations. Less than 10% of the dose-equivalent rate in air is due to gamma rays.

Formulas for predicting dose rates in air from $^{252}\text{Cf}$ sources are given in Table I.

**TABLE I**

Dose-Equivalent Rates in Air from $^{252}\text{Cf}$ Therapy Needles

\[
\begin{align*}
\text{Neutron} & = \frac{23,700}{r^2} \text{ (mrem/hr)} \\
\text{Gamma} & = \frac{1420}{r^2} \text{ (mrad/hr)} \\
\text{Total} & = \frac{25,120}{r^2} \text{ (mrem/hr)}
\end{align*}
\]

where: $M = \text{microgram equivalent content of the source}$

$r = \text{distance from source in centimeters}$

These relations should not be applied to needle sources at distances less than 10 cm, where the source should be treated as a line source, rather than a point source.
Not only are dose rates higher from $^{252}\text{Cf}$ than from therapeutically equivalent amounts of radium, but shielding and storage problems are also different. Fig. 2 shows that two inches of lead will reduce the dose rate from radium to approximately 7% of its unshielded value, but will only reduce the dose rate from $^{252}\text{Cf}$ to 80% of the unshielded value.

The most effective shields for neutrons are those which contain large amounts of hydrogen, such as water, polyethylene, and paraffin.

Dose rates from shielded $^{252}\text{Cf}$ sources must be measured with care. Since the average neutron energy of these sources (2.34 Mev) is considerably lower than that from PuBe or PoBe sources, a large percentage of the neutrons may be reduced in the shield to energies below the detection threshold of "fast neutron" survey meters. Hence, the estimated dose may be erroneously low. The Bonner Sphere type\textsuperscript{(5)} or the Rem Counter type\textsuperscript{(6)} survey instrument is probably the best method to establish exposure rates from $^{252}\text{Cf}$ sources because they respond to neutrons having energies from thermal to 7.0 Mev.
REFERENCES


4. G. D. Oliver, Jr. and C. N. Wright, "Dosimetry of an Implantable $^{252}$Cf Source." To be published.


FIG. 1 DOSE EQUIVALENT RATES FROM $^{252}$Cf SOURCES IN AIR
FIG. 2 SHIELD ATTENUATION CHARACTERISTICS

- Lead (252Cf Neutrons)
- Polyethylene (252Cf Neutrons)
- Lead (Radium Gamma Rays)