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Focusing Collimators for Use with the Hard Gamma Emitters Rubidium-86[1] and Potassium-42

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INTRODUCTION

Although there is an extensive literature concerning the design and construction of "focusing" collimators for use with scintillation detectors, there is almost no information about units which are suitable for use with nuclides which emit very energetic gamma rays. Indeed, it is widely believed that nuclides which have emissions of over 0.60 MeV are inherently unsuited for clinical scanning procedures because of the large amounts of shielding which would be required. This report describes two collimators which have proved to be practical for myocardial scanning using Rb^{86} (1.08 MeV gamma) in dogs and K^{42} (1.51 MeV gamma) in man. A high energy gamma-ray scanner employing a tungsten collimator for studies of Ca^{47} (1.31 MeV gamma) uptake by bone has been previously described (1).

METHODS

Radiation was detected by 5.25 × 3.00 inch NaI(Tl) crystals with 5 inch phototubes (Harshaw 21S12/5E-X). Pulse height discriminators were set with the lower level placed at the point on the ascending limb of the gamma peak at which the counting rate reached approximately one-third of the maximum value. Measurements of collimator focus were made using 2 mm. wide sources mounted on a disc which was rotated continuously about the vertical axis of the crystals during counting. The radioactive source was placed at varying levels within a stack of Masonite slabs which were used to approximate the absorptive and dispersing effects of tissue. In this way the focus obtained closely approximates that

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actually present under conditions of clinical use, rather than appearing to be better, as is the case when the source is in air. The design of the collimators is shown in Fig. 1. The six round holes were arranged in a symmetrical hexagonal array.

RESULTS

The focus of the 5-inch thick collimators for Rb^{86} is shown in Fig. 2. Design of these units was based on extrapolations of formulations of the effect of hole diameter and septal thickness described by M. J. Myers and J. R. Mallard (2). In part A of Fig. 2 the isocount contour lines for a single probe are shown. Part B illustrates the effect of combining counts from two probes spaced at equal distances above and below the center of the phantom. Similar data for the 8.5 inch units used for K^{42} are given in Fig. 3.

The 5-inch unit proved to be unsatisfactory for myocardial scanning with K^{42} because of penetration by radiation from nuclide outside of the desired area,

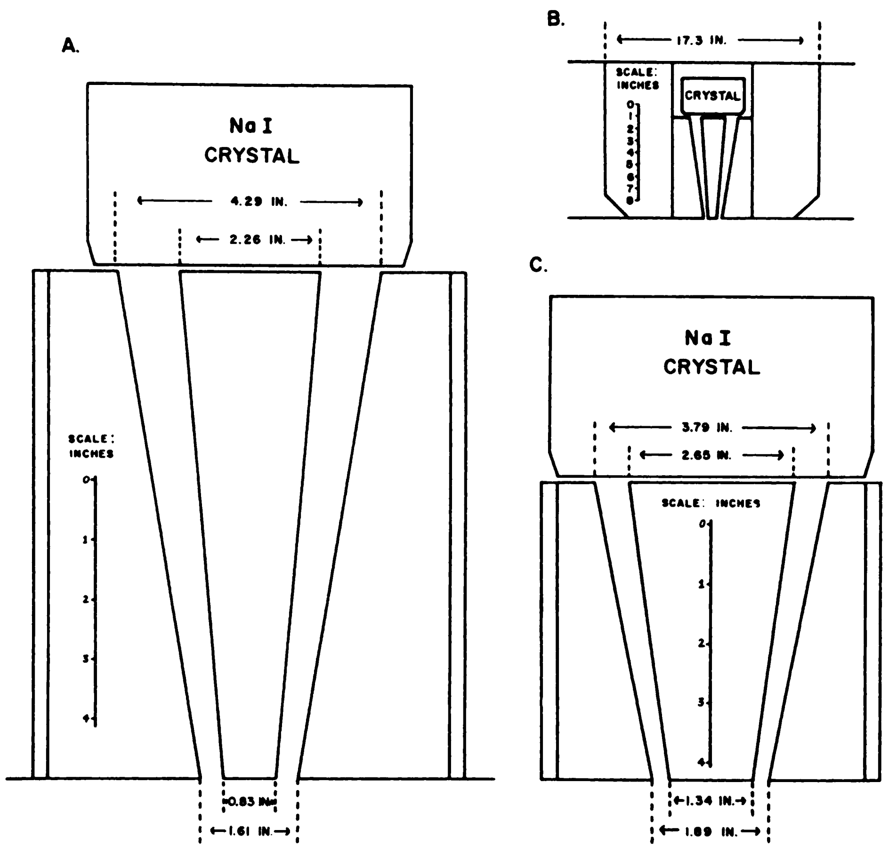

Fig. 1. Design of lead focusing collimators with 6 holes in a symmetrical hexagonal array and optical focal points 5 inches from the face. An 8.5-inch thick unit for use with K^{42} is shown in A. This collimator is shown at a smaller scale within the outer shield in B. In C, a 5-inch thick unit used with Rb^{86} is illustrated.

particularly that in the adjacent liver. On the other hand, focusing obtained with the 8.5-inch collimator was similar for Rb^{86} and K^{42}, and the counting rate obtained from a point source in Masonite at the 5-inch optical focal point of the longer unit was approximately twice that observed with the 5-inch thick collimator. These data are summarized in Table I. A source consisting of a 1.25 inch

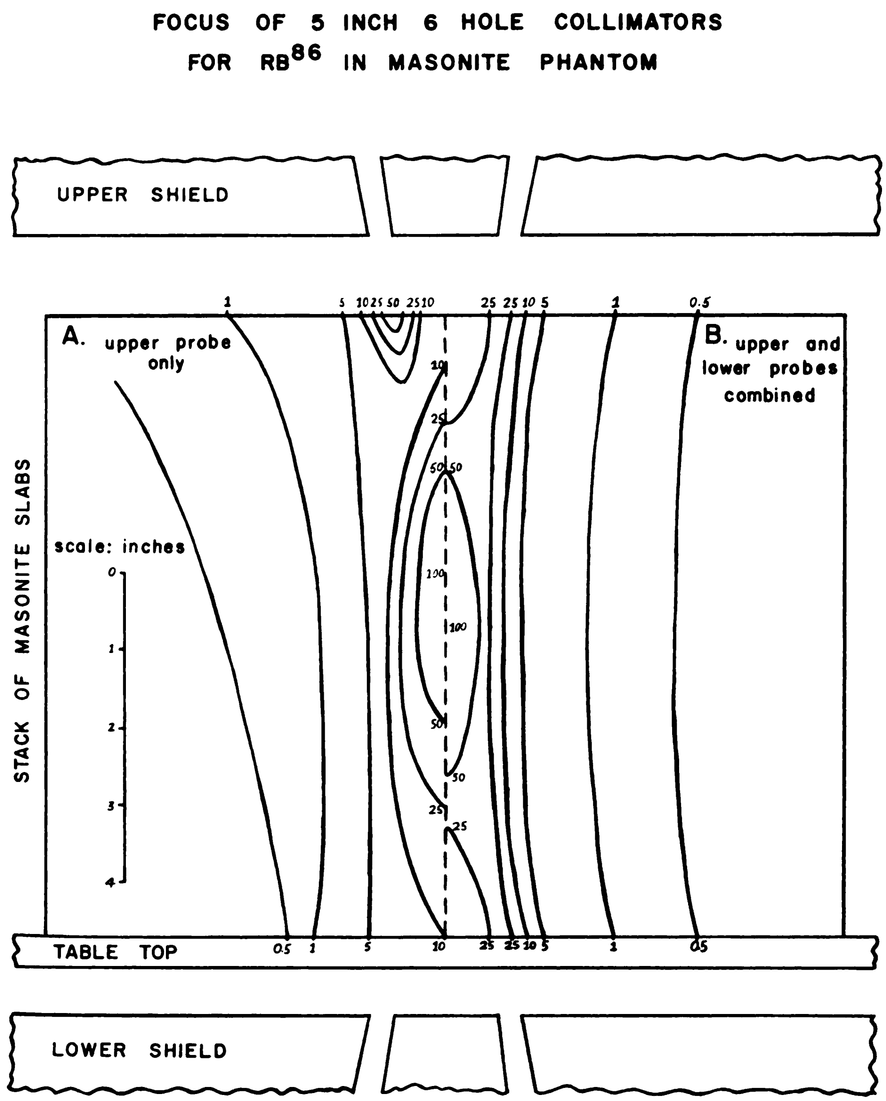

Fig. 2. Iso-count contour plots for Rb^{86} obtained with 5-inch thick 6-hole collimators placed 5 inches from the center of a Masonite phantom. Part A—upper probe alone. Part B—counts from upper and lower probes combined.

diameter filter paper disc saturated with a solution of K^{42} gave counting rates from each probe of approximately 1 cps/μC when placed in the center of the 8-inch Masonite phantom. Background averaged 1.6 and 1.9 cps for each counter at Rb^{86} and K^{42} settings respectively. This rate is comparatively high because of the small amount of shielding of the crystal in the region of the photomultiplier tube (Fig. 1B).

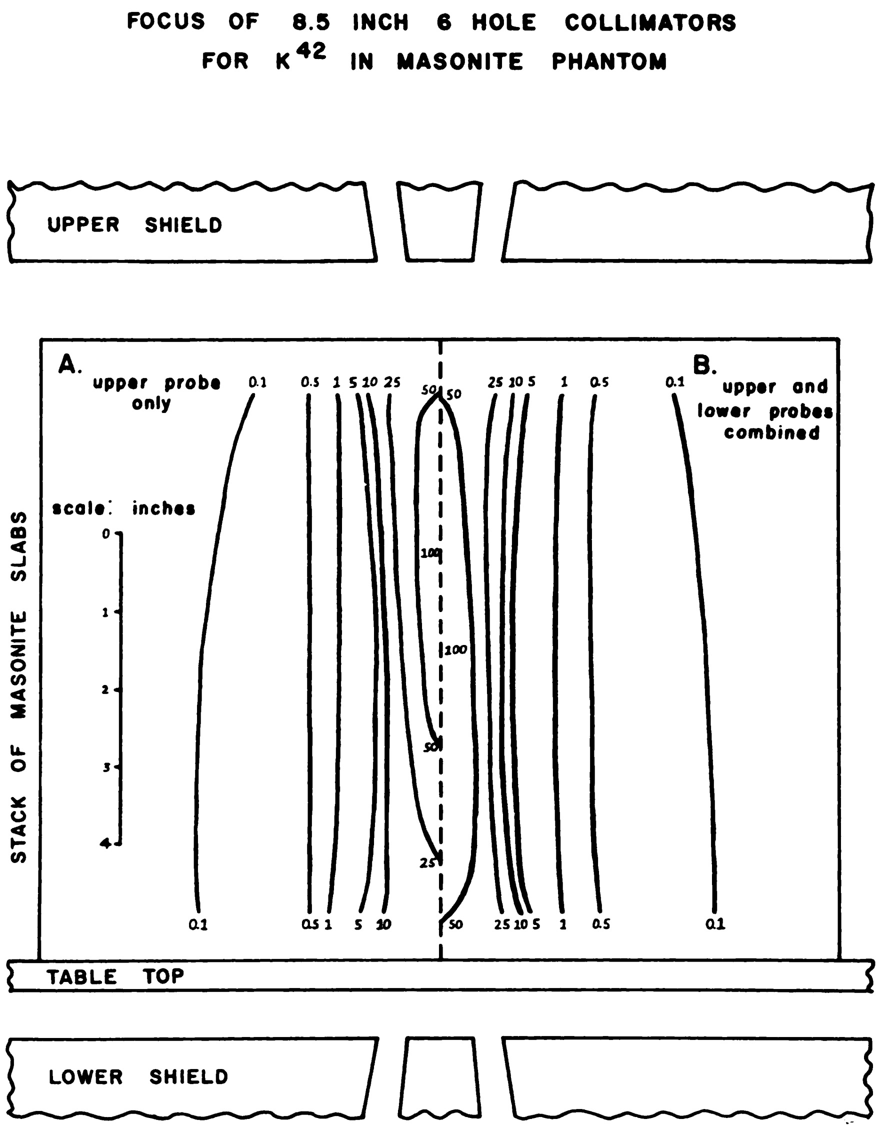

Fig. 3. Iso-count contour plot for K^{42} in Masonite phantom, using 8.5-inch thick 6-hole collimators 5 inches from center. A, upper probe alone. B, upper and lower probes combined.

DISCUSSION

The ease with which collimators and shielding for soft gamma radiation can be constructed and mounted and the reduction in radiation load associated with the administration of the less energetic emitters are advantages that have stimulated a great deal of interest in the use of this type of nuclide in clinical medicine. However, in the case of organs lying deep within the body, hard radiation is significantly less dispersed in reaching the surface and therefore should allow better definition in determinations of the pattern of distribution of radioactivity (3). The short half life (12.5 hrs) and wide distribution of K^{42} within the body result in doses of approximately 1.3 RAD to skeletal muscle for each 1.0-1.3 mc. administered (4,5). Maximum counting rates over the heart in normal man using the 8.5 inch collimators are in the range of approximately 9 cps from each probe for each mc/70kgm. injected, or approximately 4.5 times background. The shields with collimators illustrated in Fig. 1B were easily mounted on an Ohio Nuclear scanner in which minor structural modifications had been made to accommodate their weight of approximately 1100 lbs. each. They are sufficiently effective in practice to allow detection of small areas of reduced myocardial isotope uptake in the beating dog heart *in situ* (6).

While the 8.5-inch collimator is clearly superior to the 5-inch unit for both Rb^{86} and K^{42}, the results with the latter are reported since it can be used when the large outer shield needed with the longer collimator is not available.

TABLE I.

EFFECT OF COLLIMATORS AND 4 INCHES OF MASONITE SHIELDING ON THE COUNTING RATES OBSERVED FROM RB^{86} AND K^{42} SOURCES PLACED AT THE OPTICAL FOCAL POINTS. COUNTING RATES ARE GIVEN AS FRACTIONS OF THAT OBSERVED WITH THE UNSHIELDED SOURCES 13.5 INCHES FROM THE EXPOSED CRYSTAL.

	5 inch 6 hole collimator			*8.5 inch 6 hole collimator*		
	Collimator removed. No Masonite	*Collimator in place.*	*4 inches Masonite over source.*	*Collimator removed. No Masonite*	*Collimator in place.*	*4 inches Masonite over source.*
Rb^{86}	1.69	.14	.08	1.00	.27	.16
K^{42}				1.00	.28	.17

SUMMARY

Five-and 8.5-inch thick, 6-hole collimators are described which are suitable for use with Rb^{86} and K^{42} respectively. The longer unit gives superior collimation and approximately twice the transmission of the shorter unit. The effective focus obtained in a Masonite phantom with paired opposing scintillation probes is reported.

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