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SENSITIVITY OF SCINTILLATION SCANNERS

CHARLES E. MILLER

Radiological Physics Division
Argonne National Laboratory
Argonne, Illinois

A SCINTILLATION scanner which can be used to map the distribution of radioactive materials in the human body is an invaluable auxiliary piece of equipment when used in conjunction with a low level total body counter. Scanning equipment is practically indispensable in the treatment of individuals who have accidentally inhaled a radioactive element and in the study of the metabolic pathways of a radioactive material in the body.

Unfortunately, no single all-purpose scanner can be used for all studies. The optimum design of the scanning equipment will vary depending upon the energy of the gamma ray emitted, the size of the organ to be scanned, the delineation (resolution) required, the depth at which the material is located in the body and—to some extent—the quantity of the radioactive material present. Consequently, the subject of this paper will be limited to a discussion of the sensitivity (namely, the minimum amount of gamma ray activity which can be measured in a reasonable time) which can be obtained using various-sized crystals as detectors in the scanner. The reader who is interested in using scanners to locate tumors in the brain, thyroid or liver is referred to the references (1–7) for detailed information concerning the mechanical design of these systems. The remarks which are to follow are of a general nature, to be used as a practical guide in determining the feasibility of building equipment suited for a particular study.

The sensitivity of the scanner is not limited in practice so much

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by the properties of the crystal or the mass absorption of the tissue as by the inherent properties that a scanner must possess to yield the delineation necessary to measure only those rays originating in the small volume in question. Thus, it is not the total body burden that is important but the concentration per cubic centimeter of tissue that is significant. A second limiting factor is that only a small percentage of the rays emitting in the volume being measured actually strike the crystal; that is, are emitted in the solid angle subtended by the crystal to the source. Furthermore, only those

TABLE I

Energy Mev	*Efficiency E*	*Photo Fraction f*	*E x f*	*Unscattered Escape a*	*E x f x a*
		2 BY 2 IN. CRYSTAL			
.279	.966	.829	.8	.36	28.8
.661	.765	.470	.36	.454	16.4
1.17	.631	.325	.205	.549	11.2
2.62	.510	.189	.097	.68	6.6
		4 BY 4 IN. CRYSTAL			
.279	.998	.902	.9	.36	32.5
.661	.945	.652	.62	.454	28.2
1.17	.867	.518	.45	.549	25.
2.62	.761	.359	.275	.68	19.
		6 BY 6 IN. CRYSTAL			
.279	1.	.925	.925	.35	33.3
.661	.988	.759	.75	.454	34.
1.17	.955	.639	.61	.549	33.5
2.62	.884	.492	.435	.68	29.5

gamma rays which escape without being scattered and which are totally absorbed (namely, which fall in the photo peak) can be safely assumed to have been emitted in the volume directly under the collimator.

Fortunately, for the sake of preliminary calculations, the realistic detection efficiency of a large crystal (4 in. thick or more) is practically independent of gamma ray's energy if the source is buried in the body to a depth of 10 cm. which may be considered as typical of the situation confronting the experimenter engaged in scanning the whole body. Since the crystal efficiency, the photo fraction (the percentage of those gamma rays totally absorbed to the number which strike the crystal) and the mass absorption of

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tissue decrease at higher energies, these effects practically cancel each other for the assumed conditions.

The efficiency and photo fractions, taken from the table of Miller, Reynolds and Snow (8), are given for a 2 by 2 in., a 4 by 4 in. and a 6 by 6 in. NaI (Tl) crystal in columns 2 and 3 of Table I. The percentage of the gamma rays which would escape unscattered from a depth of 10 cm. of tissue is given in column 5. The product of columns 2, 3 and 5—given in column 6—is the percentage of those gamma rays emitted toward the crystal face which will actually be totally absorbed; that is, fall in the photo peak. Note that the percentage is within 15% of 28.5% from 279 kev through 1.17 Mev for the 4 by 4 in. crystal. The percentage decreases from the high of 32.5% at 279 kev as the energy decreases but still falls within these limits down to 150 kev. Note the uniform response up to 2.62 Mev obtained with the 6 by 6 in. crystal.

COUNTING EFFICIENCY OF A 3 IN. DIAMETER BY 5 IN. LONG NaI(Tl) CRYSTAL

The sensitivity (counts per minute per μc) of a 3 by 5 in. NaI (Tl) crystal used in our laboratory will be considered first. A 5 in. long crystal was selected for two reasons. First, its energy resolution is better than that obtained with a 3 in. thick crystal and, secondly, the detection efficiency does not vary as much from 150 kev to 2.62 Mev.

The assumption is made that the crystal face is 10 cm. above the surface of the body to allow space for a collimator and that a point source is located 10 cm. deep in the body or 20 cm. from the crystal face. Under these conditions, 0.9% of the gamma rays emitted by the point source are emitted in the solid angle (β) extended by the 3 in. diameter crystal face to the source. From the constants of Table I, 30% of this 0.9%, or about 0.25% of all the rays emitted by the source, will escape unscattered, be totally absorbed and fall into the photo peak. Thus 10^{-8}c of gamma activity as a point source would yield a counting rate of fifty-five counts per minute in the photo peak and 10^{-7}c would yield five hundred and fifty counts per minute. Hence, a counting period of 20 min. in the first instance and 2 min. in the second would be required if a net signal

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of one thousand counts per point (with a standard deviation of 3%) were acceptable.

Assume that it was desirable to map the distribution in the lungs using the crude 3 in. diameter right cylindrical collimator shown in Figure 1. The lung areas, as projected on an X-ray diagnostic film, cover a surface area of from 1000 to 1200 sq. cm. or about twenty times the 45 cm. area of the face of the crystal. A counting time of

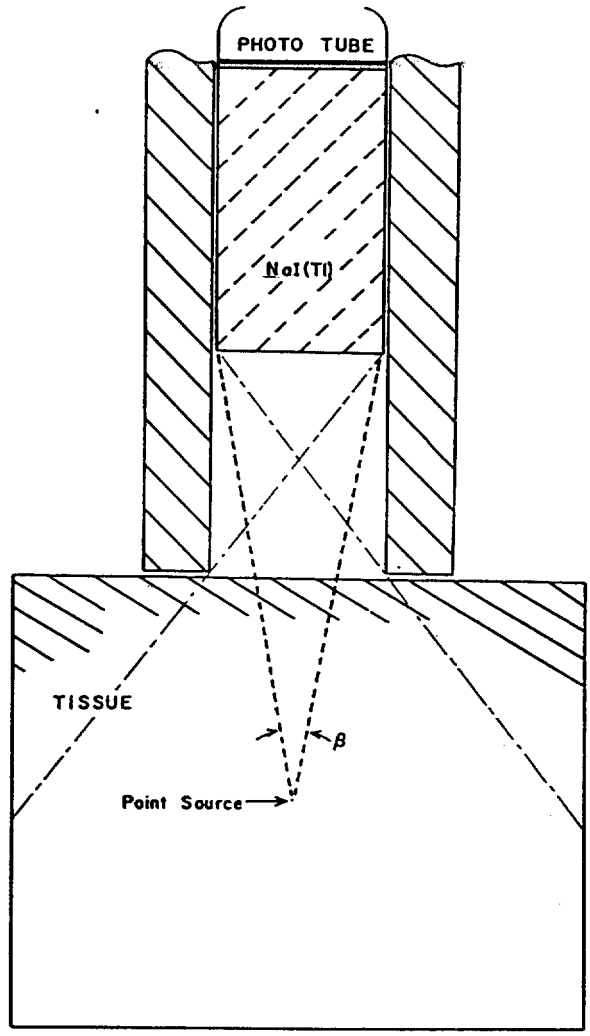

Figure 1

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40 min., 2 min. for each of twenty points, exclusive of the time required to record the data after each measurement, would be required if the subject contained 10^{-7}c in each volume or a total lung burden of 2 μc, a quantity rarely, if ever, found in an accidental inhalation case.

The delineation obtained with the scanner shown in Figure 1 is so poor that the data would be of very little value other than as

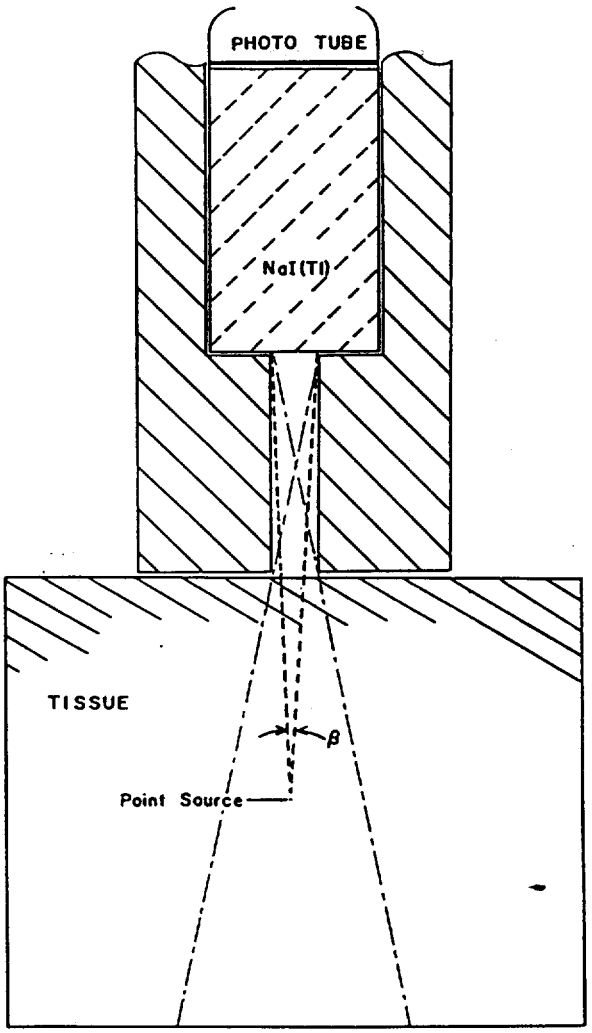

Figure 2

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preliminary data to indicate the next scan. An improved profile of the activity could be obtained with the arrangement shown in Figure 2. The diameter of the collimator has been reduced to 2 cm. Using this collimator, only 0.06% of the gamma rays emitted by the source fall in the solid angle (β) and only about 0.02% will fall in the photo peak. Thus 10^{-7}c of gamma activity at the point source will give a counting rate of sixty-two and one-half

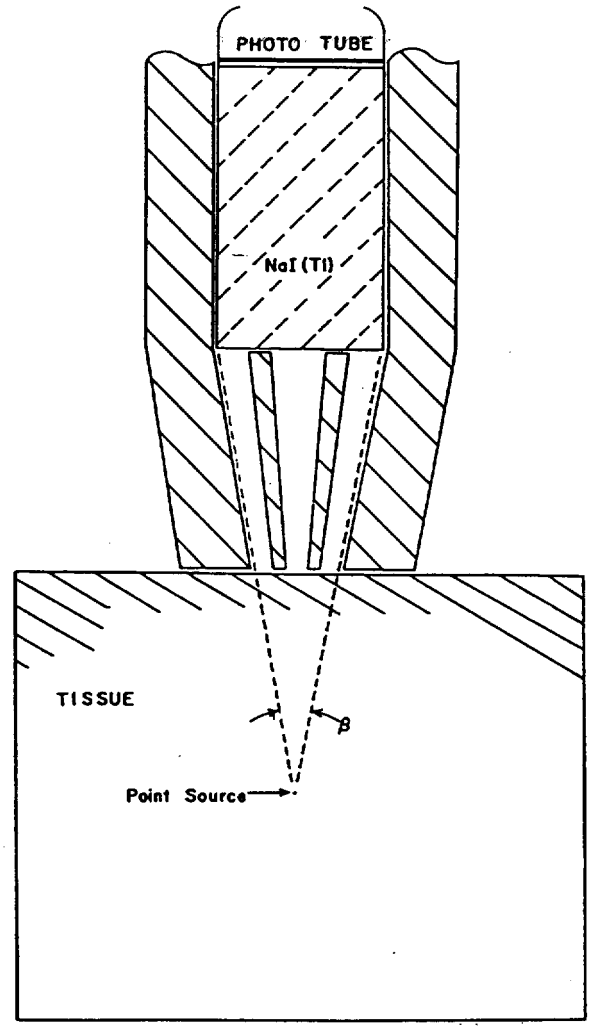

Figure 3

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per minute. At least twenty points would have to be measured for at least 10 min. each if the lung area were to be mapped of an individual who contained 2 μc. Even then, the penumbra of this collimator is such that very poor definition would result.

FOCUSSING COLLIMATORS

The best delineation will be obtained by using a focussing type collimator, a simple version of which is shown in Figure 3. The delineation obtained (the volume measured) depends upon the size and number of tapered holes used. Francis *et al.* (7) have described a focussing collimator which has a transmission of 50%. Under the conditions assumed heretofore, 10^{-7}c as a point source would yield a counting rate of about two hundred and seventy-five counts per minute in the photo peak. A great number of measurements, requiring many hours, would be required to map an organ or organs, such as the lungs, since this type of scanner accepts rays from a fairly small volume. A large total quantity would have to be present in the lungs, assuming the material was spread throughout the lungs, since the two hundred and seventy-five counts per minute from 10^{-7}c is obtained just from that volume being measured.

LARGE CRYSTALS

The number of measurements required to map an area is a function of the delineation required and does not depend upon the counting rate. Naturally, the length of time any point is counted will depend upon the counting rate and the desired accuracy. The only way to reduce the time required to make a scan is to increase the counting rate by using a larger crystal which subtends a larger solid angle to the source. A focussing collimator must be used with the larger crystals such as an 8 in. diameter by 4 in. thick crystal if any geometrical definition is to be obtained. The counting rates mentioned above for the 3 in. diameter by 5 in. long crystal might be increased by perhaps a factor of five, if an 8 in. diameter by 4 in. thick crystal were used. Thus, something of the order of fourteen hundred counts per

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minute would be obtained from 10^{-7}c in the volume being measured. From the practical standpoint, the collimator required for an 8 by 4 in. crystal would be extremely heavy, requiring very elaborate supports.

BACKGROUND

The gamma ray background of the crystal has not been considered since the activity in the target area, rather than background, is the limiting factor when working with human beings inside an iron shielded room. The background of the 3 by 5 in. crystal is about six counts per minute under the low energy photo peaks (200 kev) and about two and one-half counts per minute under the high energy photo peaks (1.46 Mev). The background of the 8 by 4 in. NaI (Tl) crystals is about five times the background of the 3 by 5 in. crystal.

CONCLUSIONS

Very valuable data can be obtained with scintillation scanners. However, these measurements are time consuming. Very seldom, if ever, will a subject contain enough activity that a count-rate meter and an automatic scanner can be used. If an automatic crystal transport system is used, it must move at extremely slow speeds. For other than a few applications such as measuring iodine in the thyroid, each study is practically a research project in itself in that preliminary measurements must be made to roughly locate the material, and these must be followed by studies with appropriate collimators to yield the delineation required.

REFERENCES

1. Corbett, B. D., and Honour, A. J.: Design of directional counters for clinical use, Nucleonics, 9:43 (Nov.) 1951.
2. Brownell, L., and Sweet, W. H.: Localization of brain tumors with positron emitters, Nucleonics, 11:40 (Nov.) 1953.
3. Newell, R. R., Saunders, W., and Miller, E.: Multichannel collimators for gamma-ray scanning with scintillation counters, Nucleonics, 10:36 (July) 1952.

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4. Allen, H. C., Jr., and Risser, J. R.: Simplified apparatus for brain tumor surveys, Nucleonics, 13:28 (Jan.) 1955.
5. MacIntyre, W. J., and Houser, T. S.: A method for the visualization of the configuration and structure of the liver. Part B. A counting rate cut-off circuit for increased contrast in automatic scanning, Am. J. Roentgenol., 77:471 (Mar.) 1957.
6. Anger, H. O.: Scintillation camera, Rev. Scient. Instr., 29:27 (Jan.) 1958.
7. Francis, J. E., Bell, P. R., and Harris, C. C.: Medical scintillation spectrometry, Nucleonics, 13:82 (Nov.) 1955.
8. Miller, W. F., Reynolds, J., and Snow, W. J.: Efficiencies and photofractions for sodium-iodide crystals, Rev. Scient. Instr., 28:717 (Sept.) 1957.

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SUPPLEMENT
to
THE USE OF LOW LEVEL GAMMA SCINTILLATION SPECTROMETRY IN THE MEASUREMENTS OF ACTIVITY IN HUMAN BEINGS

L. D. MARINELLI, C. E. MILLER, H. A. MAY and J. E. ROSE

By

HAROLD A. MAY

Radiological Physics Division
Argonne National Laboratory
Argonne, Illinois

MR. MARINELLI has summarized the principal sources of background counts in low level gamma scintillation spectrometry and has indicated the general methods available for reducing each component. I should like to add some more quantitative data.

SOURCES OF BACKGROUND

Cosmic

Reference to his Figure 7, covering the energy range to 1.6 Mev, shows the spectra resulting after elimination of the cosmic ray and shield components. The crystal employed was 7 in. in diameter by 3½ in. thick, while the 8 in. thick shield was much smaller than the room employed in whole body counting. This accounts in part for the substantially lower background of 555 ± 10 counts per minute at Argonne National Laboratory. When the identical system was located 250 ft. underground, this figure was reduced to 380 ± 5 counts per minute. Thus 175 counts per minute, or some

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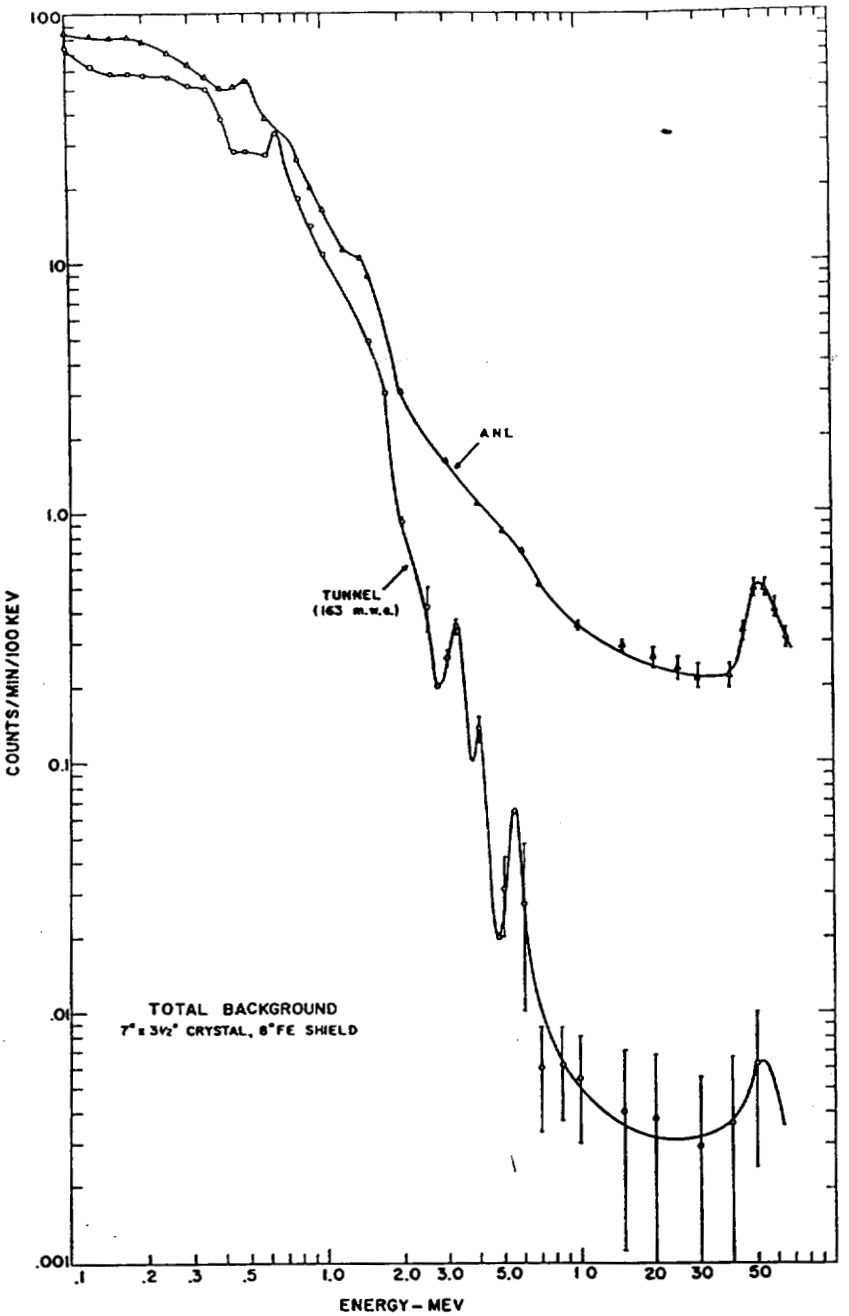

Figure 1. Typical background counting rates of a 7 by 3½ in. crystal, surrounded by an 8 in. thick Fe cave, inside dimensions of 15 by 15 by 27 in., when located at Argonne National Laboratory and under 250 ft. of rock and overlay.

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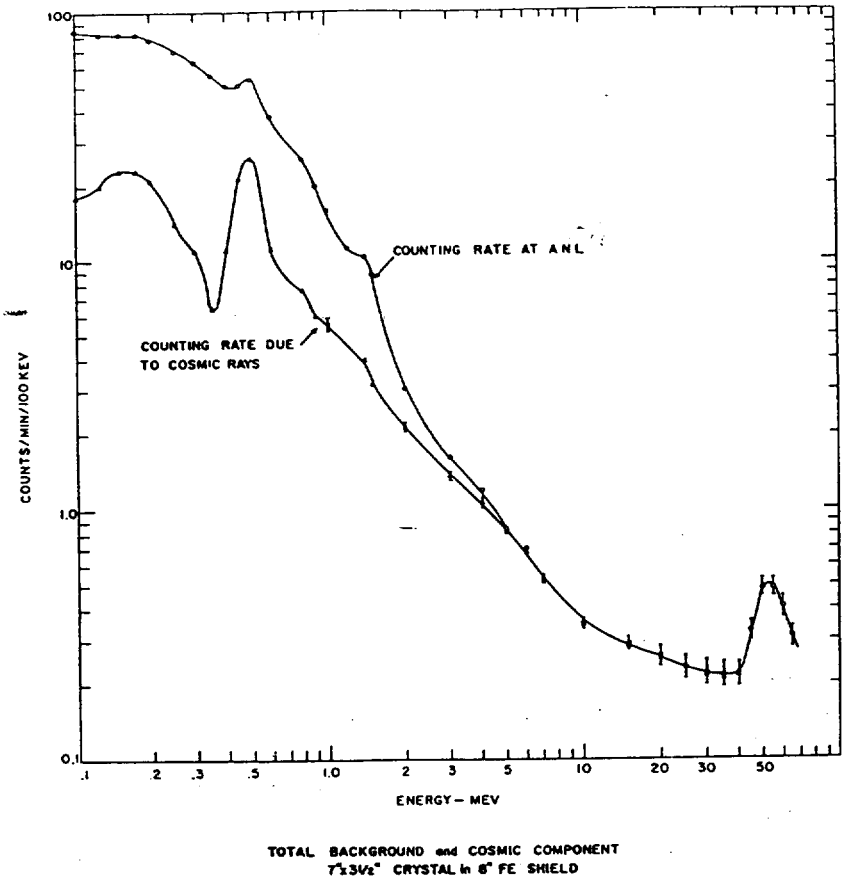

Figure 2. Total background at ANL and cosmic contribution obtained by difference of two spectra on previous figure.

35% of the original, is of cosmic origin. Surrounding the crystal with extremely pure bismuth bricks removed another 110 ± 5 counts per minute, as is shown in the third spectrum.

The background spectrum at the two locations, extended to 60 Mev, is shown in Figure 1, demonstrating quite clearly that above about 2 Mev the cosmic ray component rapidly becomes the major source of background. The peaks in the underground spectrum, at about 3.3, 4.0 and 5.5 Mev, will be explained later. In Figure 2 the difference between these curves is plotted. These figures show that elimination of the cosmic ray background *alone*

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will be most effective in a relative sense in an energy region which is not of much interest to us. The possible exceptions are in evaluation of the 2.62 Mev thorium line, or in use of summing-coincidence methods (1) for the special case of cascade transitions, such as the 1.17 and 1.33 lines of Co^{60} or the 609–770 kev transitions of Po^{214} (RaC′).

The variation of meson intensity with depth below ground is well-known and may be used to calculate the effectiveness of any underground location or other massive shield. The data of Wilson (2), with which our tunnel experiment was in good agreement, show the following:

Reduction Factor	*Depth, meters water equivalent*
3.2	15
10	40
32	80
100	160

Since suitable underground locations are seldom available or convenient, we have investigated the characteristics of large plastic anti-coincidence detectors, similar to those employed by the Rossi group at MIT for cosmic shower experiments (3). A disc 24 in. in diameter and 4 in. thick was employed (4), viewed by six type 6363 phototubes. Figure 3 shows the efficiency of charged particle detection versus discriminator bias, where the efficiency ξ is defined as the ratio of threefold coincidence counts to twofold GM counter coincidences. Typical background and Co^{60} calibration response spectra are also shown.

The penetrating or hard cosmic component varies with angle of incidence as cosine^2 θ, where θ is measured relative to the zenith. With the plastic detector located 40 cm. above the 7 by 3½ in. crystal, giving an average solid angle of 1.3 steradians, 50% of the cosmic counts *should* have been in coincidence. The actually observed reduction in counting rate in the energy range to 1 Mev was about 30% of the known cosmic component, and became less at higher energies. This can be interpreted to mean that the flux of photons and high-energy electrons arising locally in secondary cascade processes is more nearly isotropic. Thus the need for four pi geometry is implied, if 100% removal of the cosmic component

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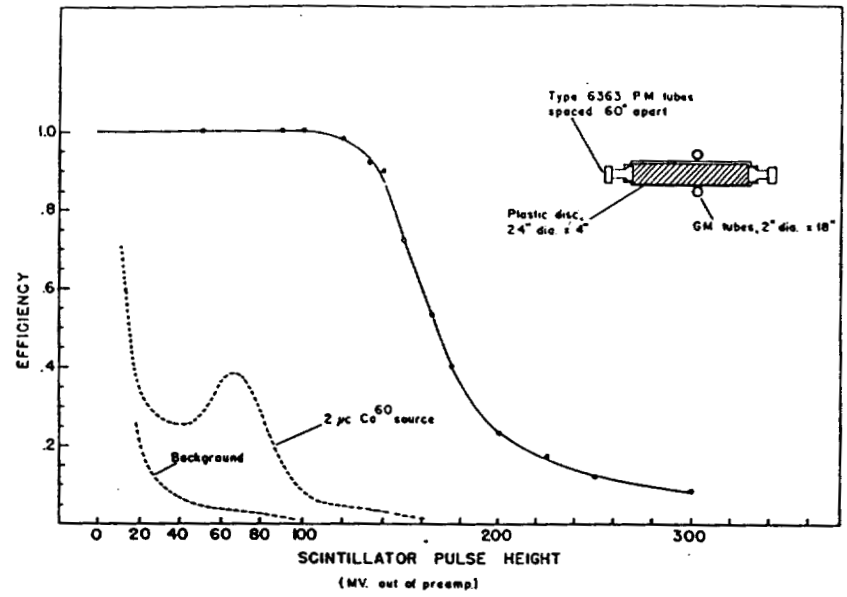

Figure 3. Efficiency of charged particle detection for large plastic detector. Dotted curves are to the same, but arbitrary, ordinate.

is to be achieved. Experiments employing such geometry have been reported recently (5) but their efficiency in eliminating the cosmic ray component has not been sought.

Shield

We now consider briefly the background contribution from the iron shield. A net difference spectrum, representing the contribution of the iron shield less any radiation penetrating or originating within 2 in. of bismuth, is shown in Figure 4. The broad maximum about 350 kev, together with the more or less well-defined peaks at 600 kev, 770 kev, and 1.1 and 1.2 Mev, is indicative of radium, whereas the peak at 2.62 Mev denotes the presence of thorium. Since no extensive surface decontamination of the ¼ in. steel plates was done prior to assembly of the cave, the possibility of surface activity cannot be completely ruled out. There has been speculation as to whether the solid armor plate used in construction of some iron rooms might not be significantly freer of contamination, but to date we have no experimental evidence bearing on the question.

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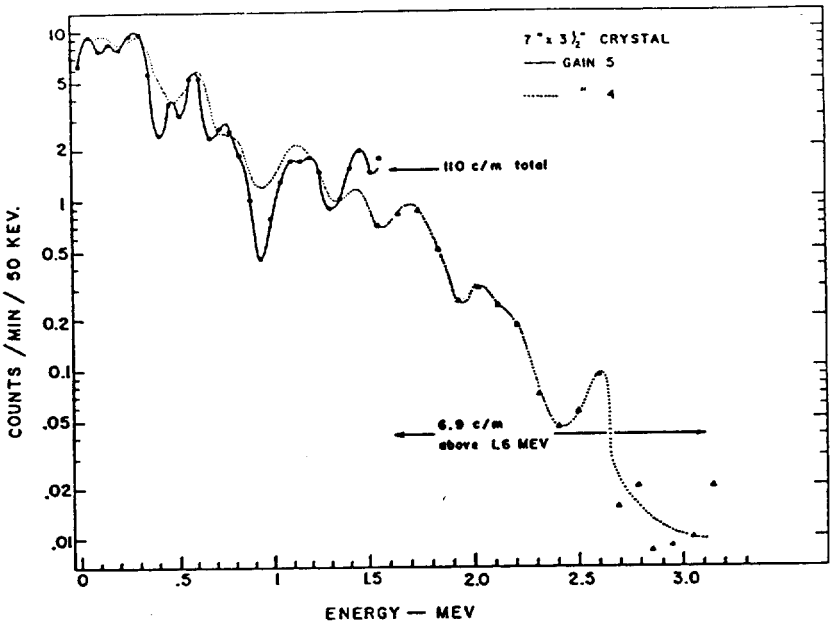

BACKGROUND CONTRIBUTION — 8" IRON CAVE

Figure 4. Portion of background due to contamination of shielding material, obtained by differences with very high purity bismuth shielding.

Crystal

Many people have noticed peaks in their background spectra at energies of 3.2 and 5.5 Mev—the energies being only approximate. These peaks are particularly noticeable in the tunnel runs. Figure 5 shows the relative prominence of these peaks in a 5 by 4 in. and 7 by 3½ in. crystal. The estimated contributions from remaining cosmic rays and from the thorium 2.62 Mev line, in the Fe cave, are shown for comparison. We feel quite sure that these peaks are from alpha particles, with energies ranging from 5.4 to 8.7 Mev, emitted by radium and thorium within the crystal. Due to the lower scintillation efficiency of NaI for heavy charged particles (6), these would appear in the observed energy region. In particular, the 5.5 Mev peak is believed to result from the beta decay branch of $_{83}Bi^{212}$ (Thorium C), followed by the alpha-emitting $_{84}Po^{212}$ (Thorium C′) with an average lifetime of 0.43 microseconds. This is because the Bi^{212} beta spectrum has a most prob-

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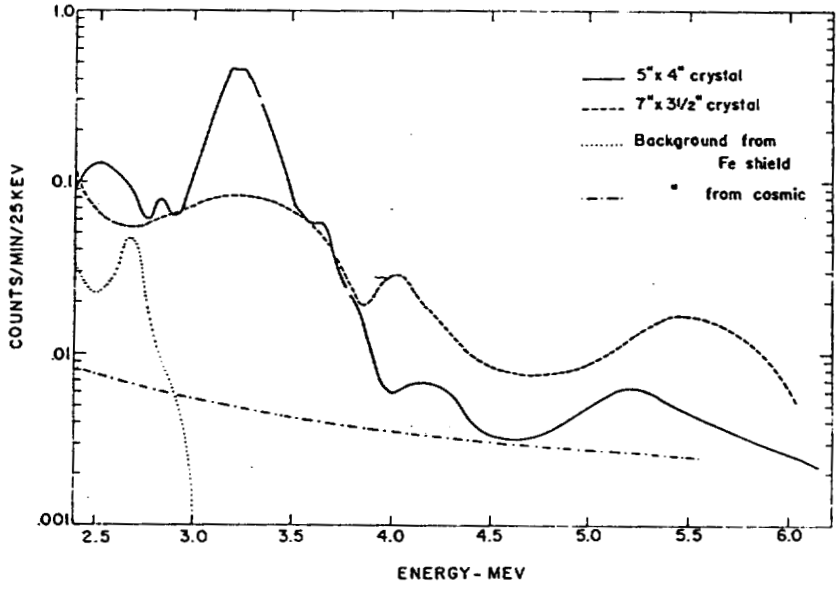
able energy of 750 kev; the alpha energy of 8.78 Mev is equivalent in light output to a 4.85 Mev electron, and the phototube anode time constant of 2 to 3 microseconds effectively sums these light pulses. The total counting rate between 4.8 and 6.0 Mev, in excess of the assumed cosmic continuum, is only 0.5 counts per minute in the large crystal or approximately 4 by 10^{-13}c. This can give at most



COMPARISON OF ALPHA PEAKS IN TWO LARGE CRYSTALS

Figure 5. Spectra of thorium and radium alpha particles; internal contamination in crystal.

about 1 count per minute below 1.5 Mev, and hence is a completely negligible source of background in the region of interest.

Phototubes

Radioactivity in the photo multiplier tubes was first recognized by Audric and Long in 1953 (7); additional data and spectra were published by Miller, Marinelli, Rowland and Rose (8). Larger crystals and better analyzers now permit improved accuracy. Table I summarizes many of our accumulated data on seven representative tube types. The probable error in estimates of total

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activity is primarily due to calibration uncertainties, rather than counting statistics; the figures shown are believed accurate to ±20%.

It is found that the use of multiple phototubes is required if the resolution capabilities of large crystals are to be fully exploited, but this usually results in an increased background. If one makes the rough approximation that the improvement in resolution is a function of total photo cathode area (that is, that photo cathode efficiency and electron collection are the same for all cathode surfaces), only then the background increase per unit area of useful photo cathode surface may be taken as a figure of merit in evaluating various tube types. This figure of merit is tabulated in the last column of Table I. Note that the values shown are not distributed at random but fall into four groups, with the 5 in. EMI quartz tubes being clearly the best. Thus, if the resolution achievable with a single 5 in. tube is satisfactory, one should use this tube for low level counting. If one needs the highest attainable resolution and is willing to accept the increased background, the quartz or vycor 3 in. tubes are indicated.

It has been shown, by crushing tubes and counting portions of glass from different regions of the envelope, that the type of glass used in the stem or "press" is consistently more radioactive than the sides or face plate. These Nonex glasses contain a few per cent of potassium, which is apparently necessary for their desired physical properties, as well as varying amounts of radium. Those interested in more detailed analysis are referred to a recent report (9).

RESOLUTION OF BIG CRYSTALS

Practical Data

Mr. Marinelli mentioned some considerations determining optimum crystal size. The choice would be relatively simple if the only *practical* limitations were price and availability. One must also consider the resolution capabilities of large crystals, particularly if the thickness is less than about 3 in. While much remains to be learned about the optical properties of large crystals, it is known that if satisfactory performance is to be obtained, every bit of crystal surface not coupled to a phototube should see a good

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reflector. An improved method of canning has been developed by Harshaw, in which each phototube has its own individual window and all the area in between is covered with the usual alumina reflector. With a 9½ by 4 in. thick crystal so packaged, to which four matched DuMont 6363's were coupled, we obtained a Cs^{137} resolution of 9%. Figure 6 shows the Co^{60} spectrum obtained, with the source about 10 cm. from the crystal face. The ratio of 1.33 Mev peak to valley is 4.35.

In order to obtain such results, it is necessary to match tubes carefully; namely, to obtain matching of their gain versus voltage characteristics whenever changes in high voltage are to be used as fine gain control. Using the split-accumulate feature of most multi-

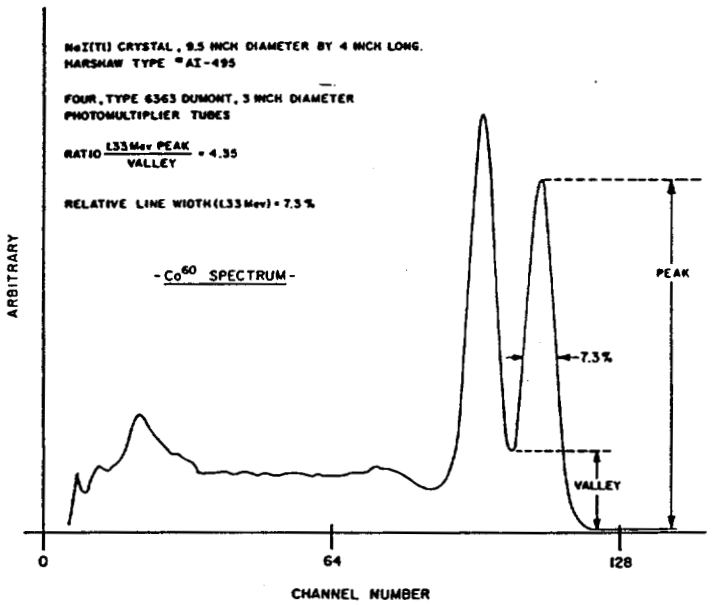

Figure 6. Resolution of large NaI crystal.

channel analyzers, the pulse-height distribution from each tube may be conveniently compared and matched. This distribution depends quite sensitively on the gamma flux distribution about the axis of symmetry, as illustrated in Figure 7. The distributions are those resulting from a single 3 in. tube, when the source was placed near the crystal face, at three locations along a diameter, as shown. Figure 8 shows the distribution obtained with the source on axis, averaged for the four tubes individually, and the result of adding

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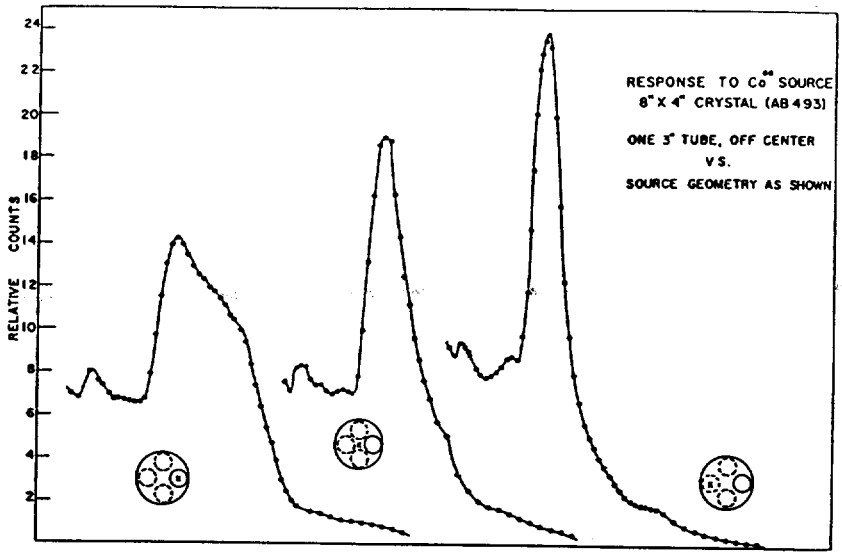

Figure 7. Variation of pulse-height distribution from a single 3 in. tube; source position moved along a diameter, as indicated. Equal counting times.

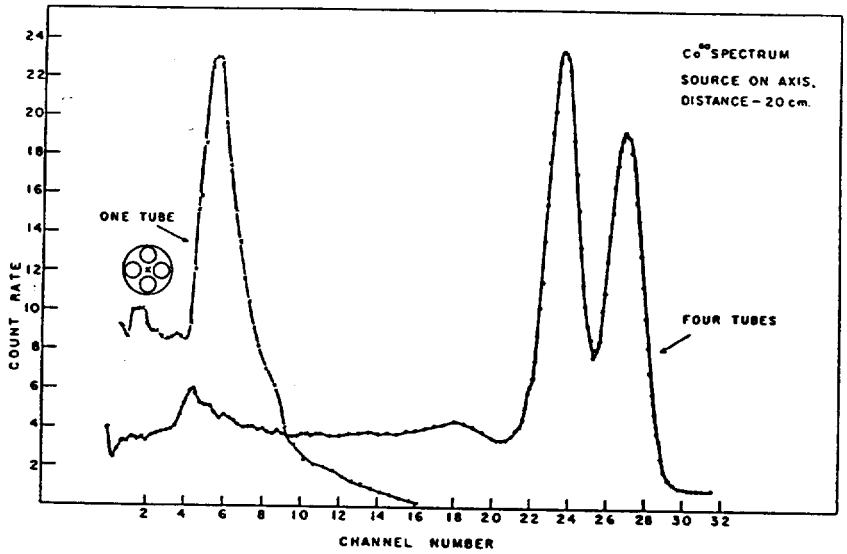

Figure 8. Average pulse-height distribution of single phototubes with source axis, and the total four-tube spectrum obtained. Peak to valley ratio equals 2.5. (Same crystal as in Figure 7.)

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them together in time coincidence. These figures indicate that some care should be used in source placement, or the results obtained may be misleading.

Theory

The resolution at some specified energy—usually the 662 kev Cs^{137} line—is a convenient indication of the performance of a given system but does not tell enough. One would like to have also a figure of merit for the crystal package as a unit. It was shown by Bisi and Zappa (10) following the theoretical treatment by Breitenberger (11) that resolution η and energy are related by the expression

$$\eta^2 = \alpha + \beta/E_0$$

The constant α is determined by broadening of the line width due to statistical processes in the energy transfer from phosphor to

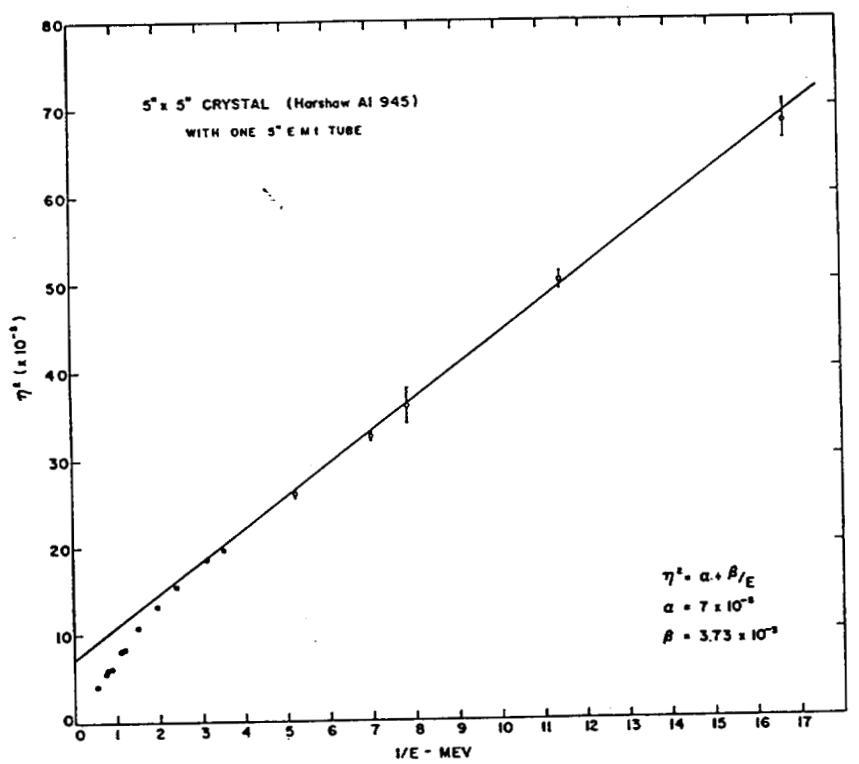

Figure 9

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first dynode, whereas the constant β depends upon the statistics of the photo multiplier and the *average* transfer efficiency. Thus the intercept of η^2 at infinite energy is more nearly representative of the crystal quality. Bisi and Zappa found that the experimental data from several 1½ by 1 in. crystals were linear for energies below about 500 kev, obtaining the average values:

$$\alpha = .0061 \text{ and } \beta = .0015$$

Data by Kelly of ORNL using a 3 by 3 in. crystal definitely did not fit a straight line. Mott and Sutton (12) discuss these experiments and conclude that there may be a portion of the transfer variance term which is energy-dependent. The experiments of Hickok and Draper (13) also suggest that this is the case, although their evidence does not appear conclusive. The data obtained at ANL with

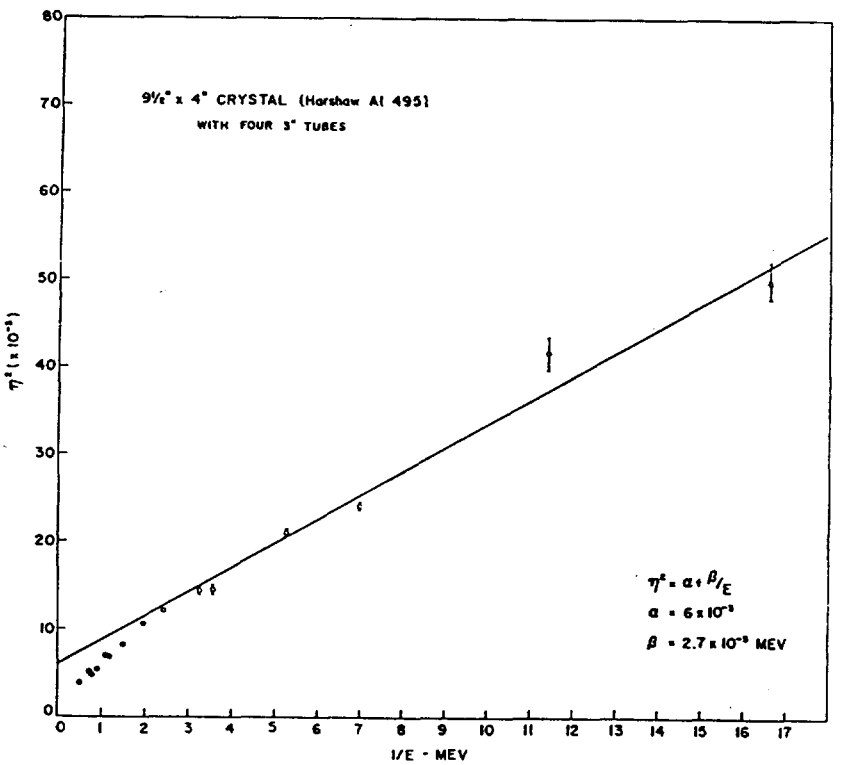

Figure 10

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several larger crystals all seem to support the straight-line relationship. Figures 9 and 10 are presented as pertinent.

It is believed that such experimental studies, coupled with analysis of the crystal-phototube optics, will lead to further improvements in the performance of large crystals, justifying their large initial cost. The increased use of large NaI scintillators in routine medical gamma spectrometry is thus anticipated.

REFERENCES

1. Hoogenboom, A. M.: Report of an international symposium held in Paris, September 1958, Nuclear Electronics, 1:127 1958. Miller, C. E.: Argonne National Laboratory Report ANL-5967, 1959.
2. Wilson, V. C.: Cosmic-ray intensities at great depths, The Physical Rev., 53:337 (Mar. 1) 1938.
3. Clark, G. W., Scherb, F., and Smith, W. B.: Preparation of larger plastic scintillators, Rev. Scient. Instr., 28:433 (June) 1957.
4. Polystyrene-base plastic prepared by Mr. Burton Barrows of Livermore, after the method of Dr. Frank Wouters, UCRL-4516, 1955.
5. Perkins, R. W., Nielsen, J. M., and Diebel, R. N.: Total absorption gamma-ray spectrometers utilizing anticoincidence shielding; Ellett, W. H.: A total absorption gamma-ray spectrometer combining sodium iodide and plastic scintillators. Papers presented at the Gatlinburg Symposium on Total Absorption Gamma-Ray Spectrometry (May 10–11) 1960.
6. Eby, F. S., and Jentschke, W. K.: Fluorescent response of NaI(Tl) to nuclear radiations, The Physical Rev., 96:911 (Nov. 5) 1954.
7. Audric, B. N., and Long, J. V. P.: The background and C^{14} detection efficiency of a liquid scintillation counter, J. Scient. Instr., 30:467 (Dec.) 1953.
8. Miller, C. E., Marinelli, L. D., Rowland, R. E., and Rose, J. E.: Analysis of sources of background in NaI crystals, IRE Trans. Nucl. Sci. NS-3:90, 1956.
9. May, H. A.: Argonne National Laboratory Report ANL-6104, 1960.
10. Bisi, A., and Zappa, L.: Statistical spread in pulse size of the scintillation spectrometer, Nuclear Instr., 3:17 (July) 1958.
11. Breitenberger, E.: Scintillation spectrometer statistics, Progress of Nuclear Physics, 4:56, 1955.
12. Mott, W. E., and Sutton, R. B.: Scintillation and Cerenkov counters, Encyclopedia of Physics (S. Flugge, Ed. entitled Nuclear Instrumentation II), 45:86, 1958.
13. Draper, J. E., and Hickok, R. L.: Dependence of scintillation counter resolution on shape of light pulse and anode time constant, Rev. Scient. Instr., 29:1047 (Nov.) 1958.

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QUESTIONS AND DISCUSSION

CHAIRMAN, W. F. BALE: To open the discussion I would like to call on Mr. Harold May of Argonne National Laboratory who has some interesting data about the problems concerned with background reduction about which he will talk.

HAROLD A. MAY: (See Supplement to "The Use of Low Level Gamma Scintillation Spectrometry in the Measurements of Activity in Human Beings" by Marinelli, Miller, Rose and May, which amplifies Mr. May's discussion.)

CHAIRMAN: Do we have a question or discussion?

HARRIS D. LEVINE: Mr. May, what reflector was used in the two crystals described last? Was this aluminum oxide? Measurements in our laboratory indicate that aluminum oxide does contain considerable amounts of radium, enough to be analyzed chemically. This may be an indication that we should all go over to magnesium oxide in preference to aluminum since Harshaw did send me large samples of each and one was clean and the other was not.

HAROLD A. MAY: We have counted some aluminum oxide and found no radioactivity. I have also counted some Linde "A" powder—which is aluminum oxide as you know—that was also a 200 to 300 Gm. quantity, and counting carefully over long periods of time we could not detect any gamma activity. This, of course, is looking at the matter rather sensitively.

HARRIS D. LEVINE: Using the bulk counters that we have at the Health and Safety Laboratory we do get enough material in to count it efficiently and according to our Analytical Division there is radium present or radium-like materials.

HAROLD A. MAY: I am not saying that there may not be, but I think that from the resolution of these peaks one would expect it in the crystal and not just on the surface. The crystal reflector is magnesium oxide, incidentally.

MARVIN A. VAN DILLA: I should like to ask Mr. Weiland what hap-

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pened to the resolution of the 8 by 4 in. crystal when he put the lucite pipe on.

RAYMOND L. WEILAND: It got about 10% worse. It went from about 9% to about 10% for Cs^{137}.

STELIOS REGAS: Mr. Weiland suggested that I bring to the attention of the group the fact that we found considerable Co^{60} in some shields in steel. We traced it back to the steel mills which are using it for detection of the deterioration in the lining of their furnaces. The problem, of course, is primarily financial because whoever is going to use the shield does not want the cobalt. We had some discussion with Mr. Hitch of the Atomic Energy Commission about it and, of course, the steel fabricators and steel suppliers know nothing about contamination and therefore cannot accept specifications indicating low contamination. There are several problems. Who is going to do the testing and how long is it going to take? An average sample takes approximately 15 to 20 hrs. before the cobalt peaks are identified in small quantities of sample. Also, the steel suppliers want a purchase order before they cut big chunks of steel for testing purposes.

JAMES W. HITCH: In checking with the Division of Licensing and Regulation of the Atomic Energy Commission, we find that one major company is licensed to use cobalt for this method of detecting deterioration in furnace linings, so it looks as if the problem not only may be cobalt getting into the melt that is being used for steel, but also it may be that some of the old steel coming into this country from other foreign producers is contaminated. The cobalt detection method is being used both in Russia and England and by other continental groups.

B. G. DUNAVANT: We approached a steel company about providing us, free of charge, with enough steel to build a room. Conveniently, it happens that the president of our university is a member of the board of directors of this steel company. We consulted with the chairman of the board who sent us to the president who sent us to the vice-president who in turn sent us to the director of research. They have no idea of Co^{60} contamination in their steel, so this next week they plan to determine if such contamination exists; and, if they find the Co^{60} in their firebrick lining results in contamination, they plan to find another way of carrying out their firebrick studies, say with cesium or Co^{60} or ceramic pellets or some other such technique.

HARRIS D. LEVINE: There are now three that we know of, including the one in the Middle West. According to R. E. Owen of Harwell, the English product is thoroughly contaminated. The problem, therefore,

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is getting quite serious, but it is before the Commission at the moment, anyway.

JAMES B. AUSTIN: If Mr. Regas has found Co^{60} in his steel, one cannot argue with the fact. I would only reply to the comment that the steel companies know nothing about it and are not concerned by remarking that we are supporting this symposium here today.

STELIOS REGAS: I am terribly sorry, Mr. Austin. I meant the steel vendors, not the manufacturers. The information about England that Mr. Hitch mentioned is that 80% of their steel is contaminated, so watch out!

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