LOS ALAMOS SCIENTIFIC LABORATORY
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LOS ALAMOS, NEW MEXICO 87544

# OFFICE MEMORANDUM

MONITORING

TO : Dean Meyer, H-1
C. W. Christenson, H-7

DATE: April 5, 1972

FROM : Jack Healy

SUBJECT: MONITORING OF SOLID WASTES AT THE 10 nCi/GRAM LEVEL

SYMBOL : H

Following our discussions on March 23, 1972, I have taken a preliminary look at the possibility of monitoring trash types of waste (papers, rags, etc.) for plutonium, prior to packaging. Such a concept is probably viable only if some processing of the wastes is carried out prior to shipment or if the economic or other factors favor reduction of the material to be handled as contaminated. However, in view of the studies of waste processing and handling to be carried out in H-7, such a scheme would appear to be possible and should be considered as a possible part of the overall study to permit further segregation and minimization of the volumes of contaminated materials to be handled.

The work to date has been strictly an attempt to assess the feasibliity of detection using available information on the sensitivity of the FIDLER probe as one example of a device for measuring the 17 keV photons from plutonium, with no attempt to optimize any of the parameters through selection of crystal size, crystal design, geometry, shielding for background lowering, etc. Similarly, little thought has been devoted to handling systems, contamination problems, sorting and all of the other mechanical aspects. However, the conclusions from even these preliminary considerations indicate a quite reasonable potential for such a system.

The basis for the estimates was the available data on the calibration of the FIDLER for 17 keV x-rays emitted in 4-5% of the disintegrations of $^{239}Pu$. This instrument uses a 5-inch diameter and 1/16th-inch thick crystal of sodium iodide housed in a 5/32-inch stainless steel can with a 0.01-inch beryllium window. Calibration data have been presented by Tinney in the routine Livermore radiation control program reports. These calibrations were performed by moving a point source of $^{241}Am$ across the detector face at distances of one, two and three feet from the crystal and measuring the counting rate at inter-

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vals. The response to an area source was then determined by weighting the counting rate at each of the radial distances by the annular area represented at that distance and integrating. A summary of the emissions of these photons and his calibrations is given in Table 1.

Table 1.
Tinney Calibration at One Foot

| | $^{238}Pu$ | $^{239}Pu$ | $^{240}Pu$ | $^{242}Pu$ | $^{241}Am$ |
|---|---|---|---|---|---|
| 17 keV x-ray per Disintegration | 0.1055 | 0.048 | 0.10 | 0.10 | 0.376 |
| Point Source | | | | | |
| Cnts/min per μg | 38,300 | 61.8 | 494 | 8.16 | - |
| Cnts/min per μCi | 2200 | 1000 | 2200 | 2100 | - |
| Area Source | | | | | |
| Cnts/min per $\mu g/m^2$ | 18,800 | 30.3 | 242 | 4.0 | - |
| Cnts/min per $\mu Ci/m^2$ | 1080 | 500 | 1070 | 1030 | - |

Since his radial response curves were difficult to read in the range of 0-100 cm of interest here, data on several FIDLER probes, again at a distance of one foot, were obtained from J. Lawrence and the response in the 17 keV band plotted. This response curve is shown, normalized to the response with the source at the center as unity, as the top curve in Figure 1. (This curve is labeled as 0 $gm/cm^2$ of water.) These response curves were measured using a point source of $^{241}Am$. For these measurements, a source of 11.2 μCi gave about 46,000 counts/min at the center and one foot from the crystal. This counting rate corresponds to about 520 counts/min per μCi of $^{239}Pu$ or about 32 counts per minute per μg, about one-half of the value quoted by Tinney. Lawrence indicated that the area calibration differed from Tinney's by only 20-25% and the difference in these two is not explained. We will use the lower value from LASL in our appraisal of the feasibility of the method.

The calibration obtained by this method represents a source with no absorbing covering and no self-absorption (i.e. a "thin" source). Our interest, however, is in a "thick" source with the

plutonium distributed through the source thickness. At these energies, the absorption is largely by the photoelectric effect and is strongly dependent upon the atomic number of the absorbing material. This is illustrated in Table 2 where the absorption coefficient for several materials and the resulting reduction factor in passing through a thickness of one gram per $cm^2$ is given.

Table 2.
Absorption of 17 keV Photons

| Material | $\mu/P$ $cm^2/gm$ | Reduction for 1 $gram/cm^2$ |
|---|---|---|
| Lucite (methyl methacrylate) | 0.77 | 0.46 |
| Water | 1.16 | 0.31 |
| Aluminum | 5.2 | 0.0055 |
| Concrete | 5.6 | 0.0037 |

This sensitivity in absorption with the composition of the source will make the measurements based on the 17 keV photons somewhat sensitive to the composition of the trash and its effective atomic number even for a system which permits the measurement of the same mass thickness of material. If desired, one could devise a system to measure the effective atomic number of the material by measuring the absorption of a beam of low energy radiation but this refinement has not been further considered. Since much of the trash will be cellulose, we have used the absorption coefficient for water with, however, the understanding that the presence of large amounts of materials with a higher atomic number (such as polvinyl chlorides) could affect the quantitative results.

To convert the measured radial response curve to similar curves for a thin layer of plutonium beneath a known thickness of shielding, each of the measured response points for the zero shielding were corrected by the absorption calculated for the slant height thickness of the source from that point to the center of the crystal. This ignores the increase in distance of the plane by the thickness of the shielding material and the

slightly greater radius if the measurement is made to the top of the overburden, but for the small thicknesses encountered in this problem the correction will be slight. The corrected curves for various thicknesses of overburden, taking into account the attenuation of the overburden, are given as the remaining curves in Figure 1. Each of these curves represents a thin source of plutonium at the depth indicated in the assumed water medium. These curves can be converted to area sources at the indicated depth by weighting each point by the area represented and integrating. Such a series of curves is given in Figure 2 where the counting rate for the given area sources at various overburdens is presented. For a thick source, then, the counting rate will be the integral under these curves out to the source thickness desired. These results are given in Figure 3 and represent the counting rate for a uniformly contaminated medium at a level of 1 nCi/gram with the source at the thickness indicated and the radius indicated. For example, a source 40 cm in radius and with a thickness of one gram per $cm^2$ would give a counting rate of 680 counts per minute per nCi/gm in the source.

The background counting rate for the FIDLER instrument is reported by Tinney to vary from 130 counts/min in a building at Livermore to 400 counts per minute at the Nevada Test Site over an area of sand covered with sagebrush. The 400 counts per minute value is high with the next lower value at 260 counts per minute over a compacted gravel road. Of course, in the field type of instrument, the amount of shielding and care taken to minimize background is small and one should be able to incorporate additional shielding to lower this background, and, more importantly, to keep it relatively constant when a fixed type of monitoring device is considered.

It should be recognized that the calculations are based upon a uniform contamination density throughout the entire mass of the source. In practice, the contamination may be spotty as, for example, the presence of one wipe or glove containing the bulk of the plutonium. There are many tradeoffs in the design which can be made such as increasing the number of crystals, changing the spacing of waste to crystal, etc., but the device requires averaging over a reasonable quantity of material to achieve the sensitivity.

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As one illustration of a possible use, without further consideration for providing the optimum in sensitivity or ease of use, one could visualize a simple system where the waste is compacted in a layer one gram per square centimeter thick with a 40 centimeter diameter radius. With the crystal one foot above the center of the mass, the counting rate above background indicated by Figure 3 would be about 680 counts/min for a uniform contamination density of one nCi/gm. Such a configuration would contain some 5000 grams of waste or about 11 pounds. If placement and measurement took one minute (30 sec. count), this would permit a throughput of some 600-700 pounds per hour or about 5000 pounds per day. Of course, a continuous conveyor system may be more convenient, but this calculation indicates the capacity. It is estimated that the output of such trash at Los Alamos is about 75,000 $ft^3$ per year with an average density of 5 pounds per cubic foot for a total of 375,000 pounds per year. At the above throughput, one could monitor this amount in about 75 days or less than 50% of the time available. Thus, even with this crude appraisal, there is room for further refinement in the handling and measuring times. To illustrate the effects of nonhomogeniety in this particular system, a one μCi source at the center would give about 500 c/min as compared to the 680 c/min for the 1 nCi/gm average source density. Thus, a single gram contaminated to 1300-1400 nCi/gm in an otherwise clean medium would give the same response as a uniform medium contaminated to 1 nCi/gm. From Figure 1, a source 40 cm from the center and buried under the 1 $gm/cm^2$ depth would give about 3.5% of the response of a source at the center or a single gram containing some 40,000 nCi/gm would give the 680 c/min expected for the uniform source at 1 nCi/gm. As was noted, these extremes can be modified by limiting the area measured, by using more crystals and by decreasing the space between the source and the counter.

From Table 1 it is noted that the calibration will vary only by a factor of two per μCi from $^{239}Pu$ to $^{238}Pu$, $^{240}Pu$ and $^{242}Pu$. $^{241}Pu$ will not register but the daughter $^{241}Am$ will give about 7 to 8 times the indication per μCi. The americium can be measured separately by use of the 60 keV gammas but, at the same time, a large excess of americium will affect the sensitivity for plutonium by feeding into the 17 keV channel.

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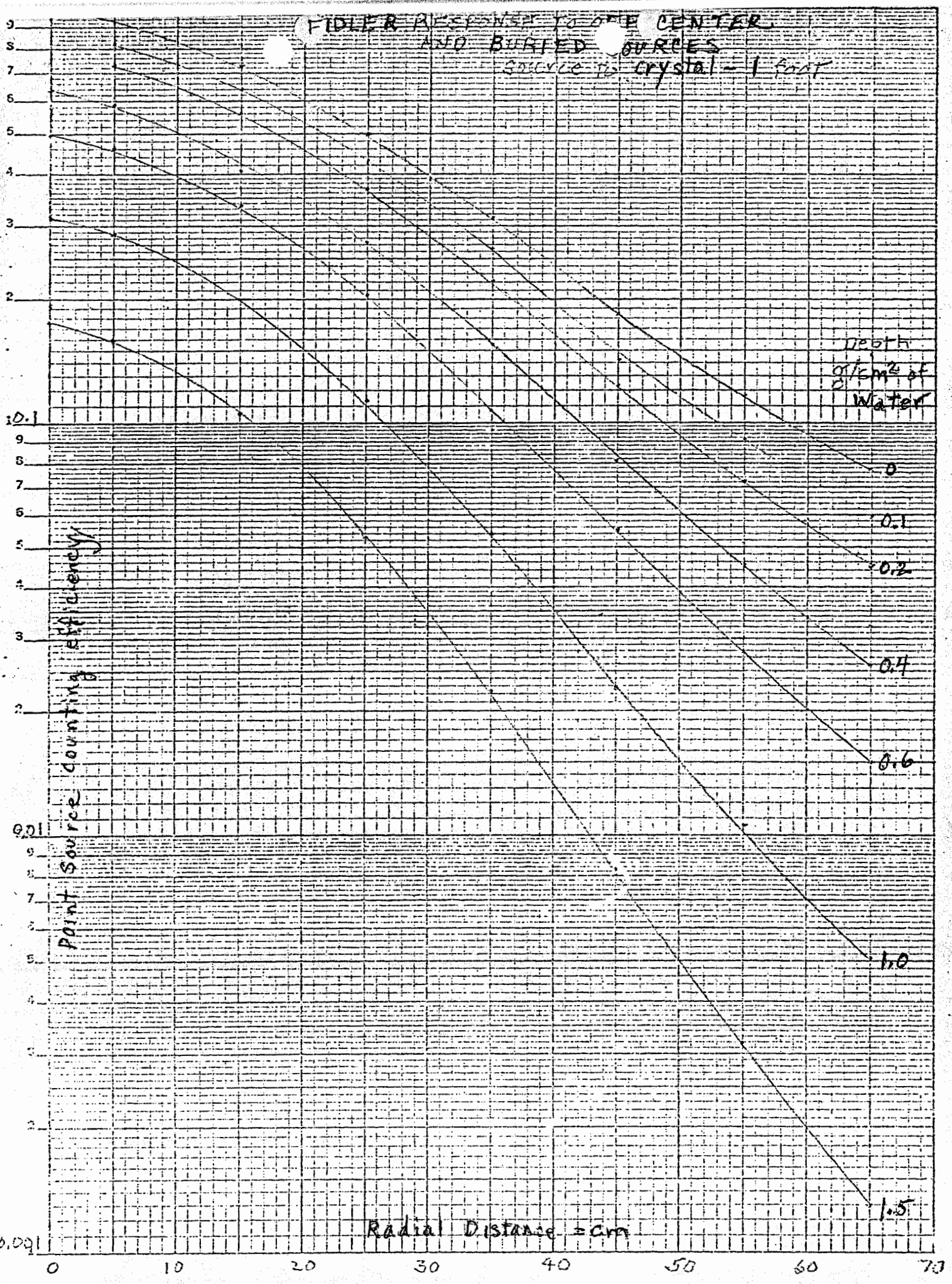
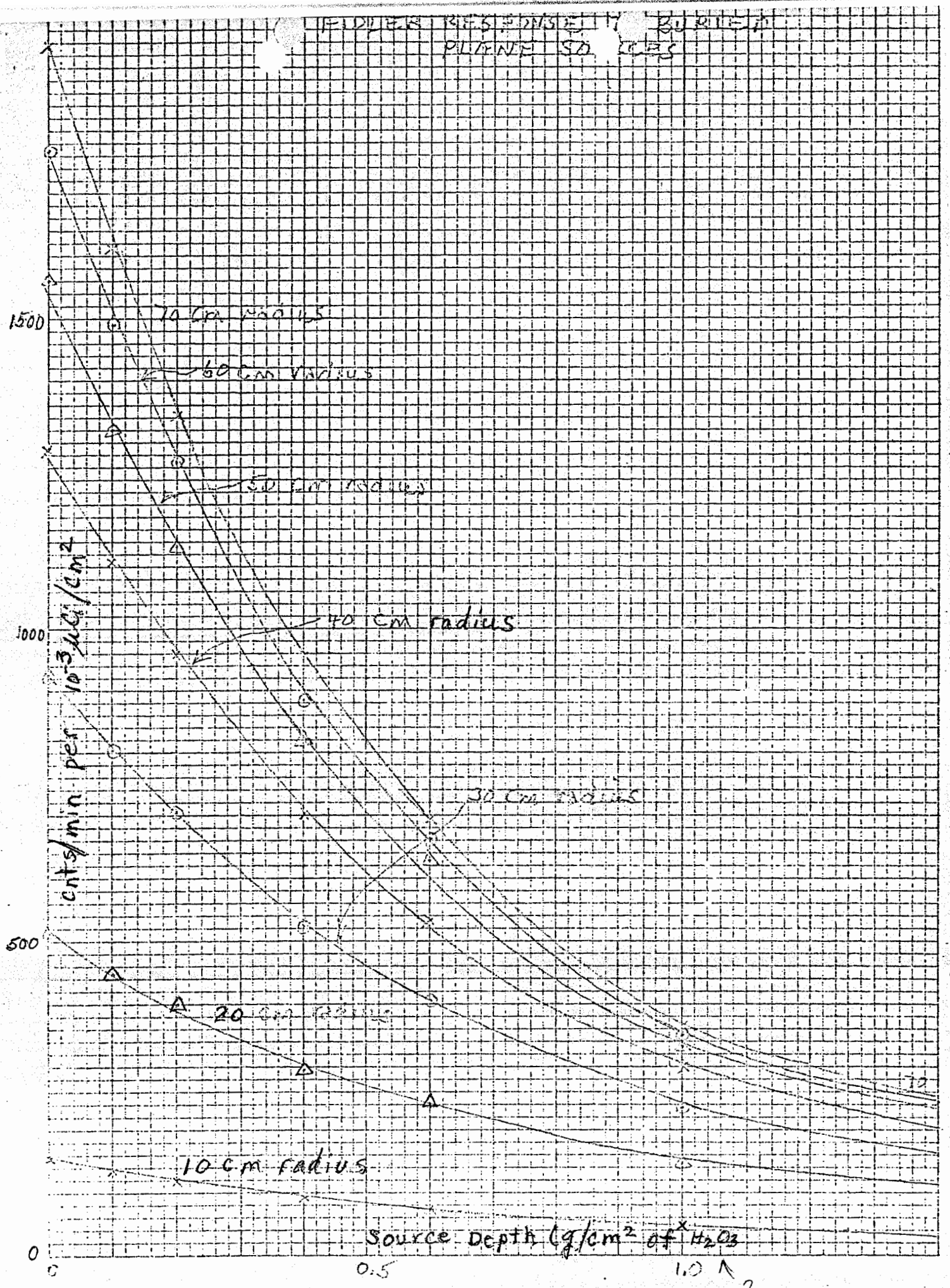
Little thought has been expended in this proposal on the handling system for presenting the material to the counter since this will depend also on the overall objectives and design of the handling system. A conveyor system could be adapted to a continuous system perhaps with automatic sorting into drums depending upon the counter response. Here shredding or other means of obtaining a reasonably homogeneous layer may be useful. Contamination control will be a problem in these handling operations. The use of a water or a soluble polymer to minimize dust may be feasible. Dean Meyer has suggested a possibility of shredding, grinding with water and extruding a layer of wet pulp. Again, if water is used, a flotation tank may be included to separate heavy objects from the trash. Certainly, considerable effort will be needed to engineer a satisfactory system.

We have concentrated on trash in this memo because of the relative non-homogeneous nature of this material. The same method could be adapted to measurement of incinerator ash or sludge from the treatment of liquids with some reduction in sensitivity due to the absorption change in higher atomic number materials but with an overall increase in confidence because of the greater homogenity of the source. We would estimate, for example, a sensitivity of the order of 200-300 c/min per nCi per gram for a material with an atomic number similar to concrete and a 70 cm radius source.

Jack Healy

JH:mp
cc: George Voelz, M.D.
E. Christiansen
Filed thru:
L. Chelius
J. Lawrence


FIDLER RESPONSE TO OFF CENTER
AND BURIED SOURCES
Source to crystal - 1 foot
Depth
g/cm² of
Water
0
0.1
0.2
0.4
0.6
1.0
1.5
Point Source counting efficiency
Radial Distance = cm
10.1
0.01
0.001
0
10
20
30
40
50
60
70



FIDLER RESPONSE TO BURIED
PLANE SOURCES
70 Cm radius
60 Cm radius
50 Cm radius
40 Cm radius
30 Cm radius
20 Cm radius
10 Cm radius
1500
1000
500
0
cnts/min per $10^{-3}$ μCi/cm²
Source Depth (g/cm² of $H_2O_3$
0
0.5
1.0
?

5 X 5 PER HALF INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

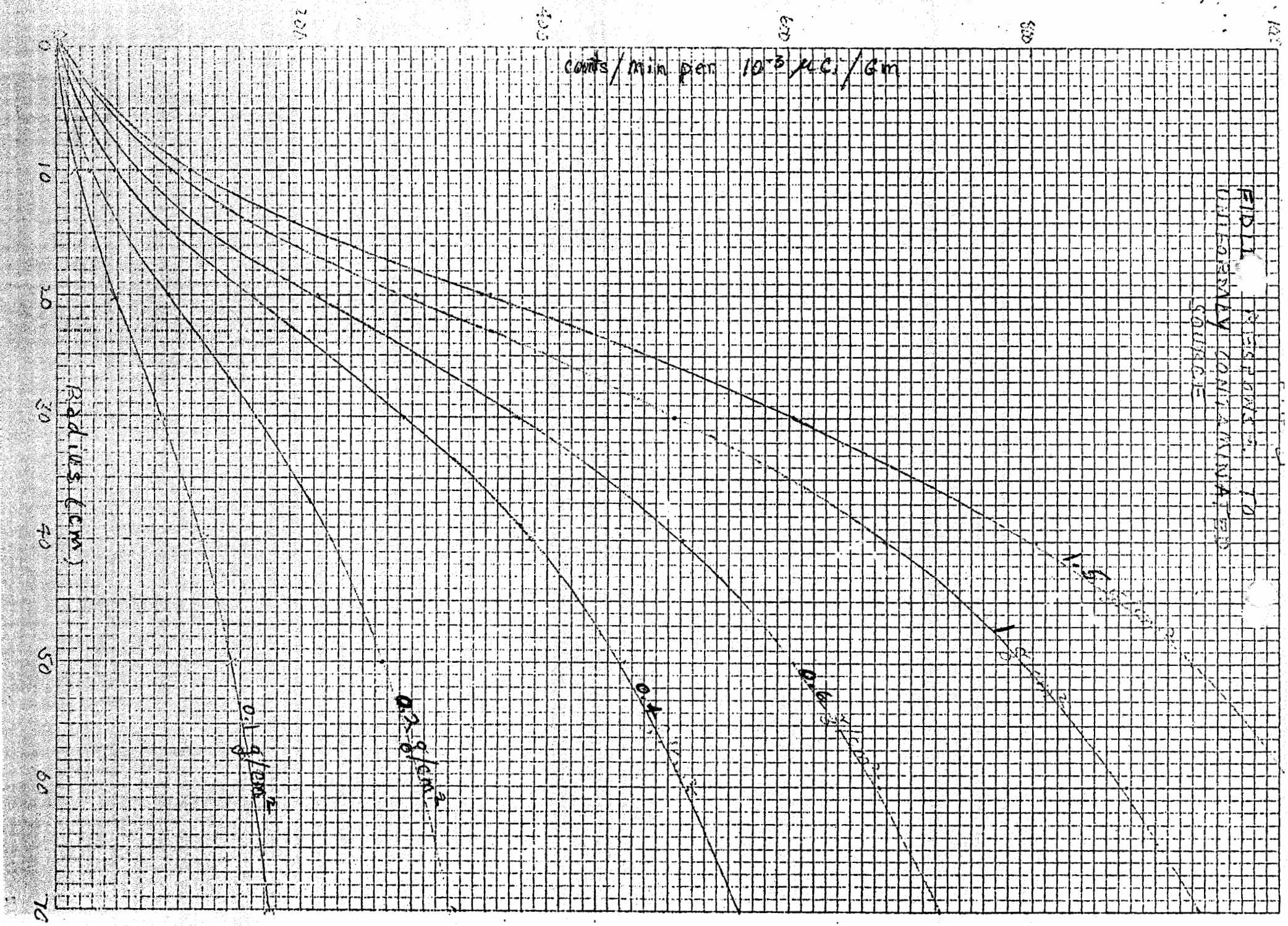



FIG. 1 RESPONSE TO UNIFORMLY CONTAMINATED SOURCE