Title: BETA CONTAMINATION MONITOR ENERGY RESPONSE

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ABSTRACT:

BETA CONTAMINATION MONITOR ENERGY RESPONSE. C.W. Bjork, R.H. Olsher (Health Physics Measurement Group, Mail Stop G761, Los Alamos National Laboratory, Los Alamos, NM 87545)

Beta contamination is monitored at Los Alamos National Laboratory (LANL) with portable hand-held probes and their associated counters, smear counters, air-breathing continuous air monitors (CAM), personnel contamination monitors (PCM), and hand and foot monitors (HFM). The response of these monitors was measured using a set of anodized-aluminum beta sources for the five isotopes: Carbon-14, Technetium-99, Cesium-137, Chlorine-36 and Strontium/Yttrium-90. The surface emission rates of the sources are traceable to the National Institute of Standards and Technology (NIST) with a precision of one relative standard deviation equal to 1.7%. All measurements were made in reproducible geometry, mostly using aluminum source holders. All counts, significantly above background, were collected to a precision of 1% or better. The study of the hand-held probes included measurements at six air gaps from 0.76 to 26.2 mm. The energy response of the detectors is well-parameterized as a function of the average beta energy of the isotopes (C14=50 keV, Tc99=85, Cs137=188, Cl36=246, and Sr/Y90=934). We conclude that Chlorine-36 is a suitable beta emitter for routine calibration. We recommend that a pancake Geiger-Mueller (GM) or gas-proportional counter be used for primarily beta contamination surveys with an air gap not to exceed 6 mm. Energy response varies about 30% from Tc99 to Sr/Y90 for the pancake GM detector. Dual alpha/beta probes have poor to negligible efficiency for low-energy betas. The rugged anodized sources represent partially imbedded contamination found in the field and they are provided with precise, NIST-traceable, emission rates for reliable calibration.

Complete Paper Accompanying the Poster Presentation at the Health Physics Society Annual Meeting, Minneapolis, Minnesota, July 12 – 16, 1998:

Beta surface contamination is surveyed at Los Alamos National Laboratory (LANL) with portable hand-held probes and their associated counters. Smear counters are used to count swipes. Air-breathing continuous air monitors (CAM) are used to monitor room air for beta emitters in some facilities. Frisking of workers includes the use of personnel contamination monitors (PCM) and hand and foot monitors (HFM). This paper reports the results of a study of the instrument response to betas from five isotopes spanning a wide range of beta energies. The study validates our calibration technique for the instruments. It provides data to make corrections to survey results when
the beta isotope is known. It provides data for making recommendations as to the best techniques for performing the surveys.

**Beta Sources:** Ten Type 36/50 anodized sources were obtained from Amersham with two activities for each of the five isotopes: Carbon 14, Technetium 99, Cesium 137, Chlorine 36, and Strontium/Yttrium 90. The respective maximum and average beta energies (keV) are: (156,50), (292,85), (1176,185), (710,246) and (2288,934). The sources are the “anodized” variety. The activity is nearly uniformly distributed (better than 6%) in a 0.3-mm-thick-anodized-disk, 36 mm in diameter, which is mounted on a 3-mm thick, 50-mm diameter aluminum disk. Hsiao-Hua Hsu of our group has performed Monte Carlo simulations of the emitted beta spectra for these sources. They are shown in Figures 1 through 5. The vertical scales are normalized to unit emission integrated over the spectrum. The beta emission rates of the actual sources, traceable to NIST, are given by Amersham, each with a stated overall uncertainty presented as a relative standard deviation equal to 1.7%. The data reported later in this paper were collected to relative standard deviations of 1% or better.

**Calibration and Test Configurations:** All counts were made in reproducible geometry. Each portable probe was held in fixed geometry with respect to the disk source, typically with an aluminum calibration jig which has a recess for the source and a recess or clamp to hold the probe above the source. “Flush”(2π) geometry results in a gap of 0.76 mm between the anodized surface of the source and the bottom of the probe, which is typically a protective grid. Calibration of portable probes is done in “flush”(2π) geometry at LANL with Chlorine-36 sources, typically of two different activities to span the range of the instrument. The calibration constant (or potentiometer) of the instrument is adjusted so that the instrument count rate (counts per minute) is equal to the beta emission rate of the source (betas per minute). The studies of response versus distance presented here were made by placing aluminum spacers between the calibration jig and the perimeter of the probe without blocking the path of betas from the source to the active region of the detector. The smear counter and the CAMs allowed direct placement of each source within the counting chamber, close to the detector. The HFM-7 hand and foot monitor counts were made by placing each source on the bar grid above the foot probe. Each source was placed in the same spot with only a small part of the 36-mm active circle occluded by two adjacent bars.

**Instrument Efficiency as Measured with the Beta Sources:** Table 1 is a detailed list of the efficiencies of the ten instruments in this study: Eberline ESP-1 with HP260 Geiger Mueller (GM) Beta Pancake Probe, Eberline ESP-1 with HP210T GM Beta Pancake Probe, Eberline RM24 with HP330 sealed gas proportional probe, Eberline E-600 with SHP340 dual alpha/beta scintillator, Eberline E-600 with SHP380 dual alpha/beta scintillator, NE Electra with DP-6BD dual alpha/beta scintillator, Ludlum 2929 smear counter with Model 43-10-1 Probe, Eberline AMS-3 CAM, Eberline AMS-4 CAM and Eberline HFM-7 P10-gas-proportional-foot probe. The column to the right shows data normalized to unit efficiency for Chlorine 36. An absolute efficiency (center column) is just the observed count rate of an instrument divided by the beta emission rate for the source. Figure 6 is a plot of the data for the HP260 beta pancake versus the average beta energy for each source. It is an example of a good probe for measuring low-energy betas. Figure 7 is a plot of the data for the SHP380 probe versus the average beta energy for each source. It shows poor efficiency for betas below 100 keV.
Efficiency versus Air Gap between the Source and the Probe: Table 2 is a detailed list of the relative efficiencies for each source and for six air gaps for the four handheld probes shown. The data is tabulated with a normalized efficiency (1.0) for the “flush” geometry with each source. In all cases the efficiency drops as the air gap increases. The small-area probe, HP260, drops more quickly than the SHP380, as expected by geometry considerations. Variations among sources for a given probe are nearly insignificant as geometry dominates. Figure 8 shows the HP260 data for Tc 99. Figure 9 shows the SHP380 data for Sr/Y90.

Conclusions and Recommendations: Dual alpha/beta scintillators are not suitable for low-energy beta surveys, i.e. average beta energy less than 100 keV. Use a pancake GM or sealed gas proportional detector for primarily beta contamination surveys. Energy response variation is about 30% from TC 99 to Sr/Y 90 for an HP260. Chlorine 36 is a good isotope for calibration. Instruments respond to Cl 36 with high efficiency and Cl 36 emits betas over an energy range typical of many isotopes. Calibration should be done with a small air gap. In addition, Radiation Monitoring Instructions should include a warning to hold the probe close to the surface, i.e. less than 0.7 cm. We recommend the Amersham anodized sources. They are rugged, have precise NIST-traceable emission rates, and represent partially imbedded contamination found in routine field surveys. We recommend calibration of a count rate meter to the emission rate of the Chlorine-36 source, i.e., meter counts per minute equal to source emission rate in betas per minute, since this is the only directly measurable physical quantity. Conversion from surface emission rate to activity per unit area depends critically on source thickness and backscatter. Typically, the backscatter compensates approximately for self absorption, so that surface activity under the probe may be estimated as about twice the measured surface emission rate. Other corrections such as efficiency variation due to known isotopes as given in this paper, conversions to activity based on some knowledge of the measurement, and conversions for the area of the probe or hot spot are probably best done off-line from the results of the surface emission survey.
Figure 1

Figure 2

Figure 3

Figure 4

Betas per MeV

Simulation by Hsiao-Hua Hsu

Simulation 90 Emission Spectrum (MCNP)

Figure 5

Betas per MeV

Simulation by Hsiao-Hua Hsu

Simulation 36 Emission Spectrum (MCNP)

Figure 6

Betas per MeV

Simulation by Hsiao-Hua Hsu

Simulation 137 Emission Spectrum (MCNP)
### Table 1

**BETA CONTAMINATION INSTRUMENT EFFICIENCY**

<table>
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<tr>
<th>Instrument</th>
<th>Isotope</th>
<th>Absolute Efficiency</th>
<th>Efficiency Relative to Cl-36 (Count/emission)</th>
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<td>Sr/Y90</td>
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<td>Cs137</td>
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Activity is approximately uniform (better than 6%) within the 36-mm diameter circle of these anodized aluminum sources.
Figure 6
HP260 Distance vs. Efficiency

Figure 7
SHP380 Distance vs. Efficiency

Figure 8
HP260 Beta Detection Efficiency

Figure 9
SHP380 Beta Detection Efficiency