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Characterization of the Eberline 1000B Multiple Source Gamma Calibrator and the Model 773 Instrument Calibrator

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The Eberline Model 1000B Multiple Source Gamma Calibrator (a.k.a. box calibrator) and the Model 773 Instrument Calibrator comprise a large part of the CEBAF Radiation Control Group's radiation detector calibration equipment. The box calibrator and instrument calibrator are used to calibrate gamma survey equipment.

In order to perform an accurate calibration, the strength of the radiation field incident on the detector must be known. This note will serve to document the characterization of the radiation fields produced by these sources.

Source Descriptions

Multiple Source Gamma Calibrator

The box calibrator consists of a steel clad, lead shielded instrument compartment, and a cylindrical lead source shield containing two source drawers with four sources per drawer. The sources are Cesium-137, and range from 378 μCi to 158 Ci (initial activities). The sources and their strengths are listed in Table 1.

The sources are exposed by pulling the source drawer pull rod to position the desired source under the beam collimating hole in the source pig. Sources may be exposed singly, or one source from each drawer can be exposed at the same time. The source drawers and the instrument compartment are "interlocked" by means of a two lock, single key system. This system prevents the opening of the instrument compartment with a

Table 1: Box Calibrator Sources

Source Number	Initial Activity	June 1993 Activity
1	378 μCi	280.2 μCi
2	8.3 mCi	6.15 mCi
3	282 mCi	209.0 mCi
4	8.58 Ci	6.36 Ci
5	3.3 mCi	2.45 mCi
6	147 mCi	109.0 mCi
7	3.05 Ci	2.26 Ci
8	158 Ci	117.1 Ci

source in the exposed position.

The instrument compartment has provision for mounting a shelf at various heights to provide the exposure rate desired for specific instrument calibrations.

Model 773 Calibrator

The Model 773 Calibrator contains a 135.6 mCi Cs^{137} source (activity certified on 11 Mar 91). The source is contained in a sealed capsule which is connected to a positioning rod, and is mounted in a steel sheathed lead shield. The source is exposed by lifting the positioning rod until the source is adjacent to the collimating port.

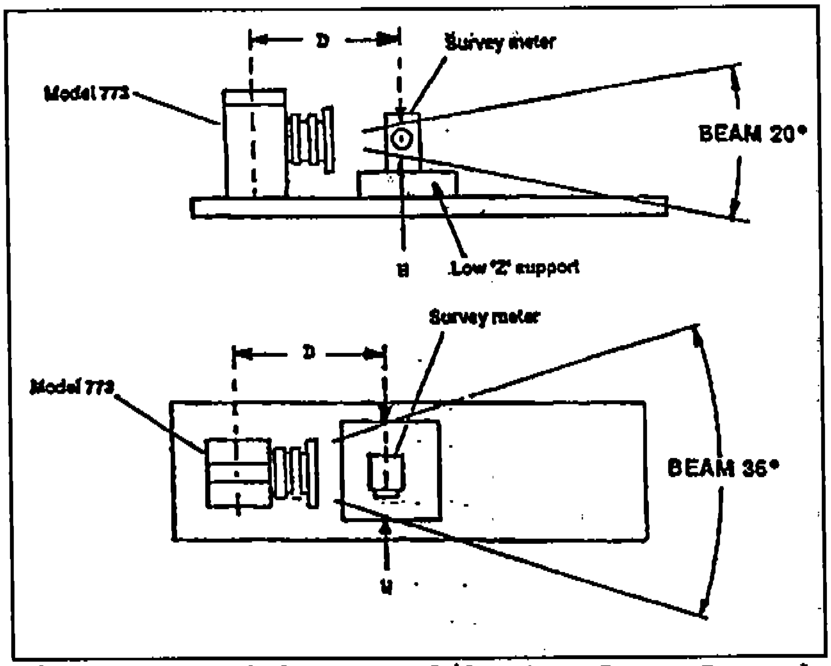


Figure 1 Model 773 Calibrator Beam Spread

The collimating port has a beam flattening attenuator which produces a radiation field whose intensity within the collimated beam is uniform in any plane perpendicular to the beam axis. The radiation beam forms a rectangular "cone" of 36° horizontal and 20° vertical (see Figure 1) with the apex at the source. There are three movable attenuators that can be positioned over the collimating port (transmission of 0.25, 0.1, and 0.1) so that an instrument can be calibrated at three points on each range without changing the meter position.

Characterization

Multiple Source Gamma Calibrator

Method

The exposure rates inside the instrument compartment of the box calibrator were determined with the RadCal model 1515 ion chamber instrument. This instrument is calibrated (NIST traceable) by the manufacturer using a Cs^{137} source. A layer of 1/8" thick plexiglass was used as a buildup cap for making the exposure rate measurements.

The instrument probe was positioned directly over the beam collimating hole on a thin (1/32") fibreglass shelf. Each source was then exposed and the exposure rate noted. After each source had been exposed individually, all possible combinations of the sources were exposed in turn and the exposure rates noted. This procedure was repeated for all of the available shelf positions.

Uniformity of the radiation field was determined for two sources at one shelf location near the center of the compartment. The detector probe was placed on a thin fibreglass shelf that had been marked off in a 1.5 inch square grid. The exposure rate was measured at each grid point. The results were used to produce a "topographical" map of radiation field at a level in the compartment. (Note that this is essentially a tomographic result.) Similar maps will be produced for each calibration position to be used, and issued as separate documents.

Results

Figure 2 shows a typical plot of the exposure rate v. distance. The lines passing through the data points were computed using a fourth order polynomial regression. (A fourth order polynomial was used to ensure a good fit at the data end points.) The data trend exhibits the inverse square characteristic expected of a point source geometry. A table of the exposure rates measured at various distances for each source can be found in Appendix A. Graphs of exposure rates v. distance for each source are included in this note as Appendix B.

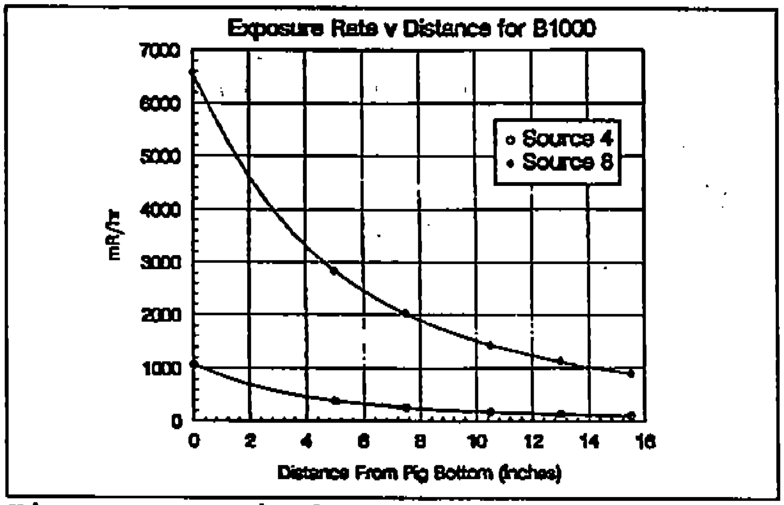


Figure 2 Typical Exposure Rate Trend For B1000 Multiple Source Calibrator

The maximum exposure rate measured was 394.8 R/hr. This measurement was made immediately over the collimating hole with the strongest source exposed. The calibrator is capable of delivering gamma exposure rates from the maximum measured (394.8 R/hr) down to about 2 mR/hr. For use at the established shelf heights, the exposure rate should be determined from the table in Appendix A. The graphs in Appendix B can be used to determine the exposure rate for any source-distance combination, but use of the graphs should be reserved for non-standard distances.

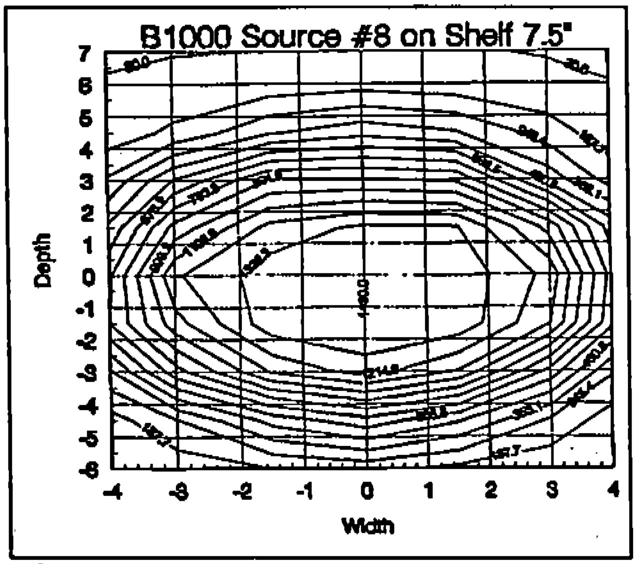


Figure 3 Isorate Contours for Source Number 8

The field uniformity was determined near the center of the instrument compartment (shelf height 7.5" above the bottom of the compartment) for source number 3 (209 mCi) and source number 8 (117.1 Ci). The readings at the grid points were used to compute lines of constant exposure rate over the shelf. (The computation was performed by the GRAFTOOL software package.) A map of the shelf showing the isorate contours was produced for both sources. The maps are shown as Figures 3 and 4; as well as in Appendix B.

Examination of the maps reveals that the exposure rate is quite nonuniform in the plane of the shelf. There is an area of about 9 square inches centered over the beam collimating hole where the exposure rate is within 10% of the center (or maximum) value. Outside this area the exposure rate drops off quite dramatically. This effect becomes more pronounced as the higher exposure rate is increased. It is expected that the nonuniformity of the field increases as the distance from the shelf to the bottom of the compartment decreases, and the field becomes more uniform as the distance from the shelf to the bottom of the compartment increases. Due to the limited area of uniform exposure rate, as well as any influence from the individual source used and the distance to the shelf,

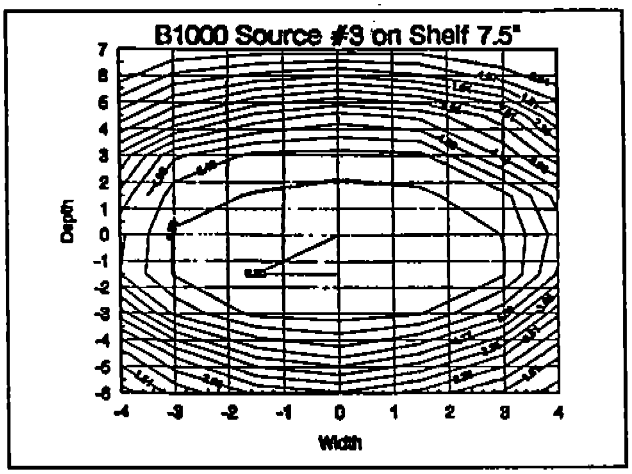


Figure 4 Isorate Contours for Source Number 3

exposure of instruments for calibration purposes should be done with the detector centered over the beam collimating hole.

Model 773 Calibrator

Method

The manufacturer of the source provided a formula to establish the distance from the source that a given unattenuated gamma exposure rate (neglecting such room effects as scatter off the walls etc.) will occur. The formula is:

$$Distance\ [cm] = 56.5\left(\frac{Source\ Strength\ [mCi]}{Desired\ Rate\ [mR/hr]}\right)^{\frac{1}{2}} \quad (1)$$

Due to the beam flattening attenuator at the collimating port, this formula should hold for any position in the beam cone. The RadCal model 1515 ion chamber instrument was used to verify both this formula and the uniformity of the beam in cross section perpendicular to the beam axis. The procedure used was the same as that employed for the box calibrator.

The contribution from scattering to the exposure rate at points along the beam center line was also determined. To measure this contribution a shield was placed between the source and the measuring instrument. The shield intercepted the entire beam so that the only radiation measured was that which was scattered into the detector's active volume. Measurements of the scatter were made at several distances from the source.

Results

Data was taken at a number of distances from the source with the detector positioned so that the beam axis coincided with the center of the active volume of the detector. The data was graphed and compared to a curve generated using the manufacturer's formula (equation (1)). The data showed good agreement with the generated curve thus verifying the usefulness of equation (1) in determining the correct source to instrument distance for a desired exposure rate. The graph is presented as Appendix C.

The effect of the beam attenuators was also investigated. The attenuators were seen to reduce the beam intensity to the level expected for the attenuator used. The attenuators are marked with a multiplication factor which, when multiplied by the unattenuated beam strength, yields the attenuated beam strength.

There are two 0.1 attenuators, and one 0.25 attenuator.

To determine the profile of the gamma beam in a plane perpendicular to the beam axis, the RadCal Model 1515 ion chamber instrument (using the 6cc chamber with build up cap) was used to measure the exposure rate at points of a grid within the plane. The first set of measurements was made at a detector to source distance of 33.5 cm. (It should be noted that 33.5 cm is the closest practical source to detector distance that can be used.)

At 33.5 cm, the exposure rate within the beam field was seen to be uniform in the horizontal direction at any given vertical distance above or below the beam center line. A plot of the field is shown in Figure 5. This plot shows the exposure rates in mRad/min in a plane perpendicular to the beam axis for the upper half plane.

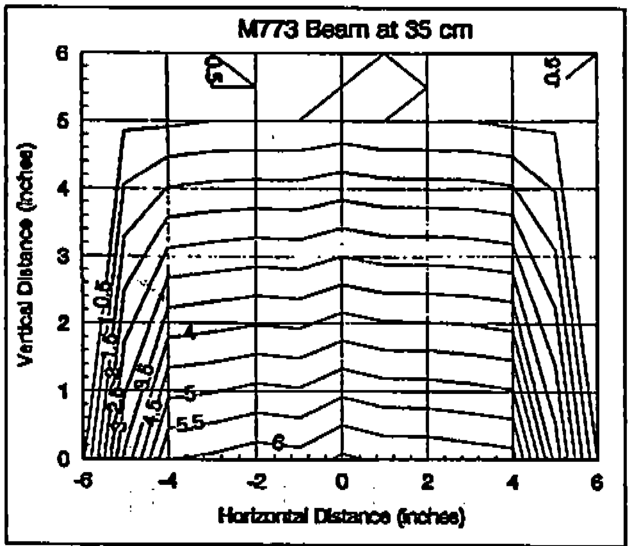


Figure 5 M773 Gamma Source Radiation Field at 35 cm (Upper Half Plane Shown).

The gamma beam at 35 cm distant is approximately 10 cm high and 20 cm wide. The plot shows that the exposure rate within the beam is quite uniform in the horizontal direction with sharp definition of the edge of the beam field. In the vertical direction, however, the measured exposure rate can change by as much as 10% over distance of an inch (2.54 cm), and over the beam height the exposure rate does not have a constant value. This highlights the importance of ensuring that the detector is placed on the beam center line within a narrow tolerance band. The maximum exposure rate at the 35 cm point was 6.5 mRad/min, and occurred at the very center of the beam.

A second set of measurements was made at a detector to source distance of 1 meter. A plot showing the exposure rates in mRad/hr in a plane perpendicular to the beam axis for the upper half plane is presented as Figure 7. At 1 meter, the gamma beam is approximately 35 cm high and 65 cm wide.

Examination of Figure 7 shows that the gamma field is uniform within the limits of the beam. The horizontal edges of the beam are well defined showing a rapid drop in exposure rate outside the beam. The upper limit of the beam was outside the range over which measurements were made, so the sharpness of the field along the upper edge was not investigated. This is not seen as being a problem since with reasonable care to center the detector on the beam center line will not result in the upper limit of the beam being approached by the active volume of any of the detectors currently in use.

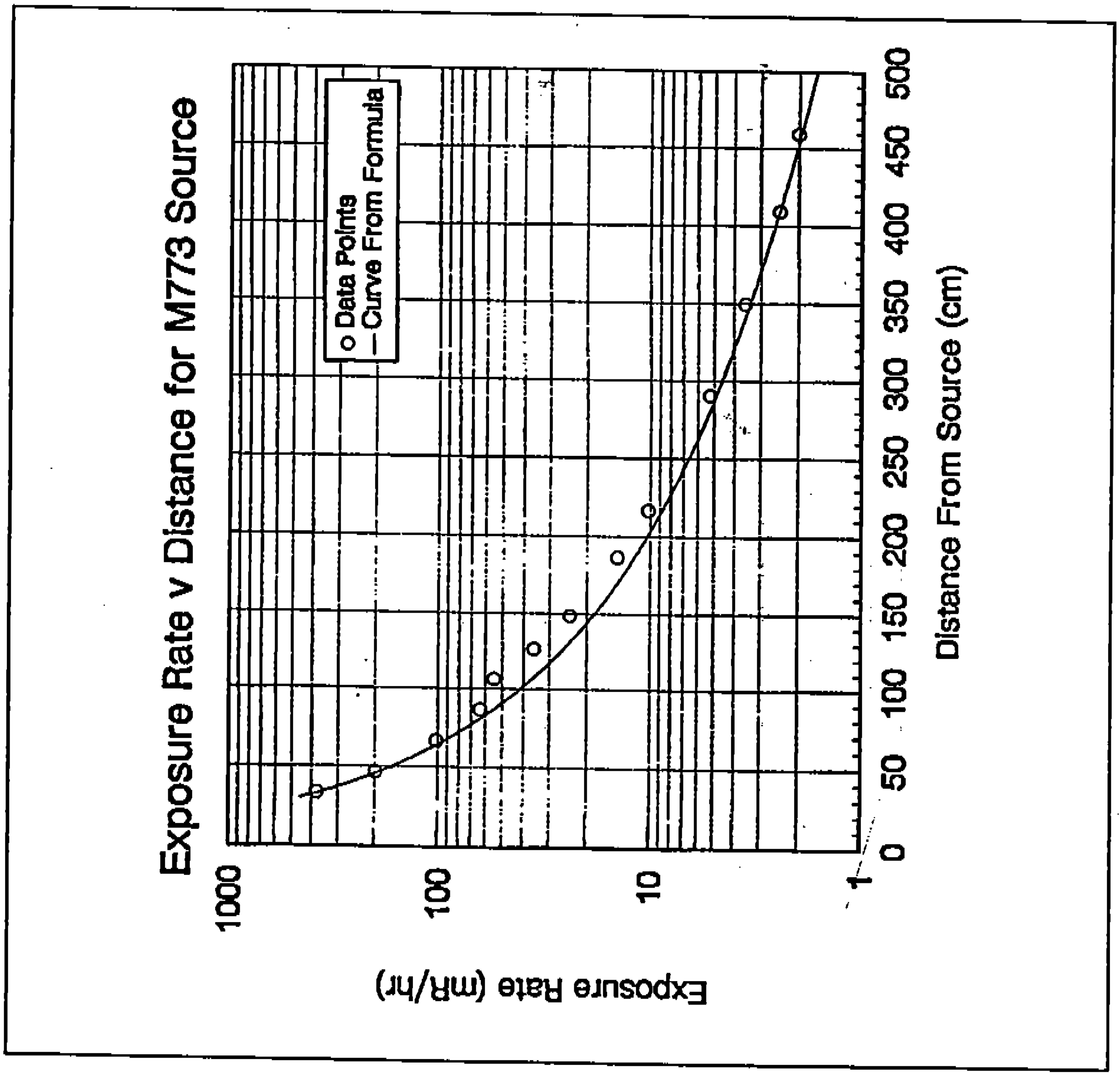
Table 2: Exposure Rates Due to Scattering for the Model 773 Calibrator

Distance (m)	Exposure Rate (mR/hr)
0.40	0.01
0.75	0.01
1.00	0.00
1.25	0.01
1.50	0.01
1.75	0.01
2.00	0.00
2.50	0.00
3.00	0.01
3.50	0.01

The contribution of scattered gammas to the exposure rate at points along the range track was measured using the 1500 cc ion chamber. The data is presented in tabular form in Table 2. The background rate during these measurements (source not exposed) was 0.01 mR/hr. This indicates that there is minimal contribution from scattered gammas to the exposure rate at points along the range track.

Conclusions

Appendix C: Measured Exposure Rate versus Distance Compared to the Manufacturer's Formula for the Model 773 Calibrator



Field Maps for the Model 773 Calibrator at Distances 35 cm and 1 m