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Item Submitted by:	Battelle Tracking No.:	N/A
Dr. Ron Demeo Radiation Shield Tech. Inc. 401 SW LeJeune Road, #200 Coral Gables, FL 33134	Date(s) of Test:	August 5-11, 2004
	Test Item:	Demron Supression Blanket
	Model Number:	unknown
	Quantity:	1
Performed under contract: Spanner/TAP Agreement #04-30	Serial Number(s):	N/A

Requested Service:

Measure the ability of the Demron Suppression Blanket to reduce radiation dose to individuals approaching gamma-emitting radioactive material that is distributed on the ground. Low angles of approach, in the range of 8-30°, are especially desired. Information on the effectiveness of both point-source and distributed source material is desired.

Materials and Methods:

The Demron Suppression Blanket (referred to as "blanket" in this report) is 36 inches by 30 inches, and weighs about 60 pounds. The manufacturer indicates it is made up of 30 layers of 0.5-mm material, so 15 mm thickness was assumed. It consists of no lead materials. The manufacturer's website claims a 30% reduction in dose rate for ^{137}Cs. To test the effect of two blankets, the blanket supplied was simply folded in half.

The measurement and test equipment (M&TE) used in the testing are listed in Table 1.

Table 1. Measurement & Test Equipment (M&TE)

M&TE Item	Item I.D.	Calibration Date
Bicron LE Detector	C727A	7-21-04
Cs-137 source	318-405	N/A
Cs-137 source	318-406	N/A
Cs-137 source	318-083	N/A
Cs-137 source	318-084	N/A
Co-60 source	318-411	N/A
Co-60 source	318-412	N/A
Co-60 source	MPS-1	N/A
Co-60 source	720-7-2	N/A
Ra-226 source	318-057	N/A

Cs-137 Fields: ^{137}Cs emits gamma-ray radiation at 662 keV energy. In order to test the dose rate reduction capabilities of the blanket for ^{137}Cs, four ^{137}Cs sources with a total activity of 14 mCi were positioned on a concrete floor in a 28' by 22' by 13' high room. Grouped together, they approximated a point-source geometry at the distances measured. Separated, they formed a distributed geometry. A Bicron Micro-rem meter was used to measure dose rates for both configurations, with and without the blanket covering the sources. For the point source geometry, the Bicron was positioned at a source-detector distance of 100 cm, at angles with the floor of 10, 20, 30 and 90 degrees. For the distributed geometry, the Bicron was positioned at distances of 70, 100, 150 and 200 cm at angles of 30 and 45 degrees with the floor. The distributed geometry consisted of a 10 mCi ^{137}Cs source surrounded by three equally-spaced 1 mCi sources 30 cm from the center source. For the distributed geometry, dose rates were only measured with the blanket covering the sources. A total of 12 independent random readings were recorded and the arithmetic mean and standard deviation was calculated.

Co-60 Fields: ^{60}Co emits gamma-ray radiation at 1250 keV energy. In order to test the dose rate reduction capabilities of the blanket for ^{60}Co, four ^{60}Co sources with a total activity of about 320 μCi were positioned on a concrete floor in a 28' by 22' by 13' high room. Grouped together, they approximated a point-source geometry at the distances measured. A Bicron Micro-rem meter was used to measure exposure rates with and without the blanket covering the sources. The Bicron was positioned at a source-detector distance of 100 cm, at angles with the floor of 10, 20, 30 and 90 degrees. A total of 12 independent random readings were recorded for each configuration and the arithmetic mean and standard deviation were calculated.

Ra-226 Fields: ^{226}Ra emits gamma-ray radiation at various energies in the range of about 186-610 keV. In order to test the dose rate reduction capabilities of the blanket for ^{226}Ra, one ^{226}Ra source with a total activity of 1.7 Ci (23 milligrams) was positioned on a concrete floor in a 30' by 30' by 30' high room. The source approximated a point-source. A Bicron Micro-rem meter was used to measure exposure rates with and without the blanket covering the source. The Bicron was positioned at a source-detector distance of 100 cm, at angles with the floor of 10, 20, 30 and 90 degrees. A total of 12 independent random readings were recorded for each configuration and the arithmetic mean and standard deviation were calculated.

Test Results and Discussion:

Cs-137 Fields: The test results for ^{137}Cs are recorded in Tables 2 and 3. Table 2 provides the one- and two-blanket attenuation factors for the point-source geometry, which are the dose rate with the blanket divided by the dose rate without the blanket. Figure 1 shows how the blanket attenuation factors change with angle. Figure 2 shows how the dose rate from the distributed source geometry changes with distance for specific angles. The data points in Figures 1 and 2 are measured data, and this data was fitted with a curve so interpolations and extrapolations could be estimated.

Table 2: Cs-137 Point source at 100cm					
Angle (degrees)	Dose rate w/o blanket (μR/h)	Dose rate with 1 blanket (μR/h)	Dose rate with 2 blankets (μR/h)	Attenuation Factors 1 blanket	2 blankets
10	2750±62	950±25	225±15	0.35±0.013	0.08±0.006
20	2850±85	1390±28	450±21	0.49±0.02	0.16±0.009
30	2950±117	1800±37	750±27	0.61±0.031	0.25±0.014
90	3000±106	2150±52	1750±42	0.72±0.034	0.5±0.026

Table 3: Distributed ^{137}Cs sources covered by one blanket at various distances		
Distance (cm)	Dose Rate (μR/h) 30 degrees	45 degrees
70	3750±100	4050±100
100	1850±100	2000±100
150	800±100	900±100
200	475±100	525±100

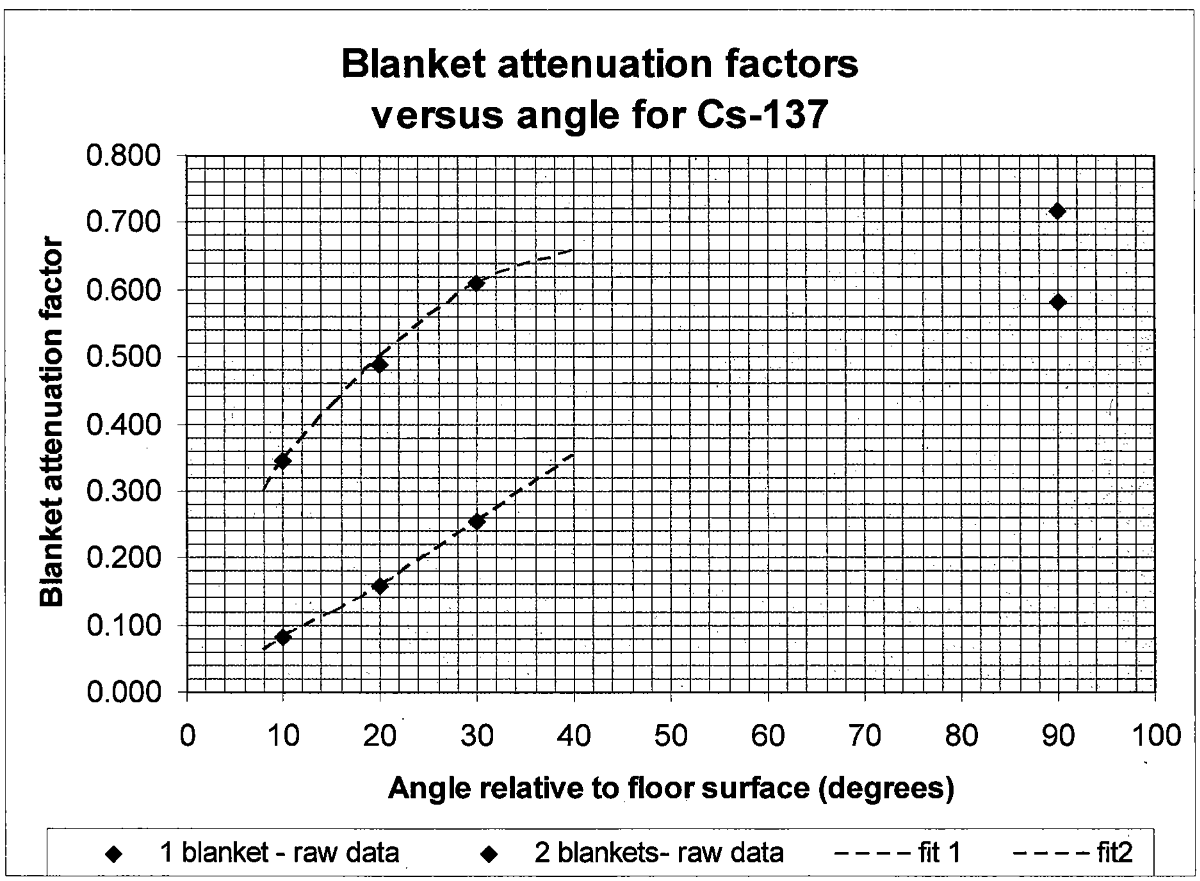

Figure 1: Blanket attenuation factors versus angle for Cs-137.

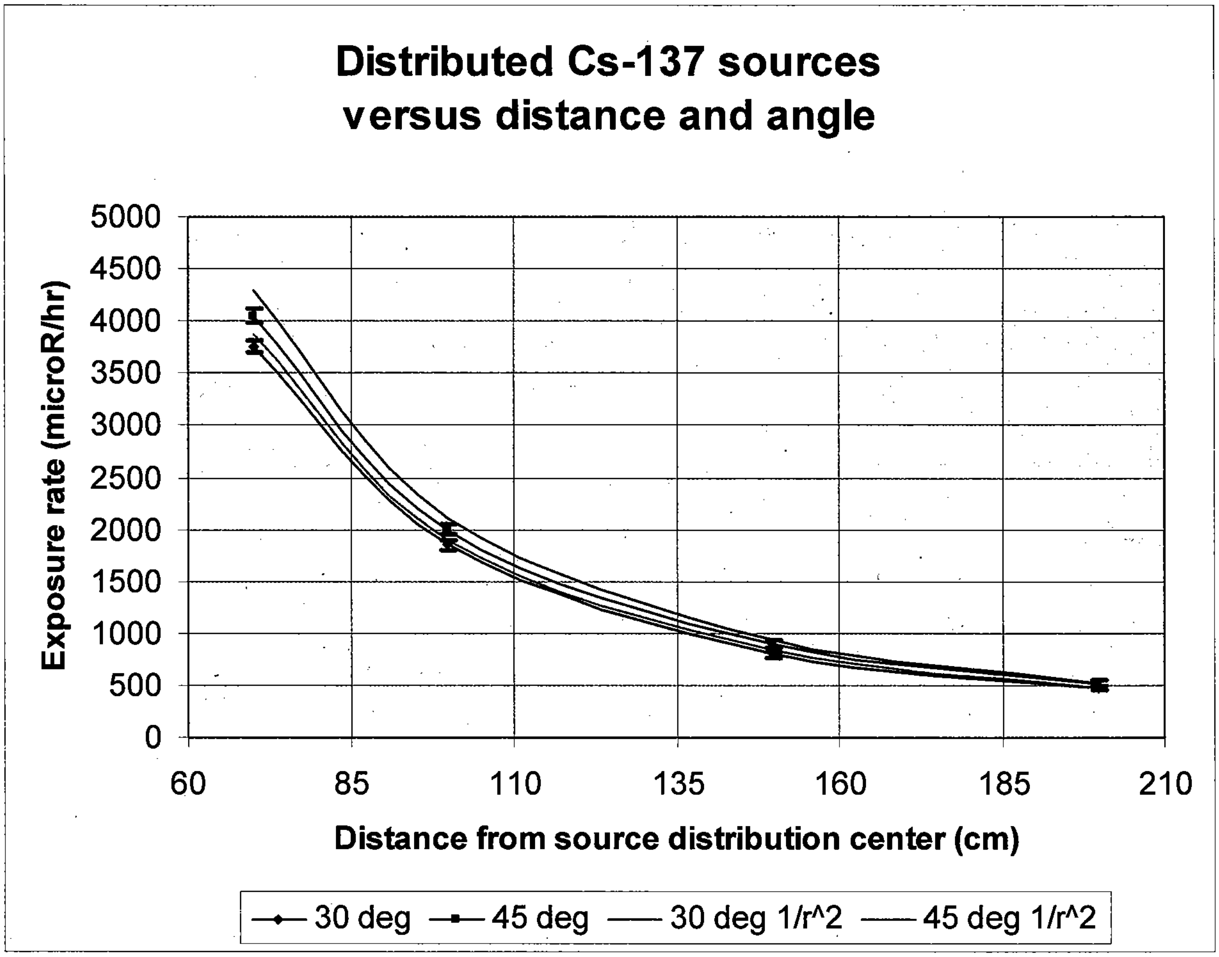

Figure 2: Dose rate fall-off with increasing distance for a distributed source geometry.

The minimum dose rate reduction is achieved at an angle of 90 degrees to the floor. This corresponds to a minimum thickness of blanket traversed by the radiation. The measured attenuation factor of 0.72 agrees with the manufacturer's statement that a dose rate reduction of about 30% is achieved with the blanket. As expected, the effectiveness of the blanket improves as the angle increases, since there is more material for the radiation to traverse at shallower angles.

The graph of the dose rate fall-off from the distributed source geometry demonstrates that the inverse-square-law applies with the blanket. If the value of 3750 μR/hr is accepted for the 30 degree angle (70 cm case), then predictions of the dose rate at the other distances can be made and compared to measurements, provided the inverse square law holds. For example, the dose rate at 100 cm for 30 degrees is calculated from

$$D_{100} = D_{70}\left(\frac{70}{100}\right)^2$$

The value of D_{100} as calculated from this equation is 1838 μR/hr, and compares favorably with the measured value of 1850 μR/hr. Calculated values compare favorably with measured values for all cases of the distributed source geometry. The dose rate fall-off from the blanket can therefore be considered as an inverse square phenomenon for practical purposes, at least for simple distributions and at distances on the order of 100 cm and greater. Plots of the theoretical inverse square dose-rate fall-off are also plotted in Figure 2 for purposes of comparison, normalized to the rates at 200 cm.

Co-60 Fields: The test results for ^{60}Co are recorded in Table 4, and include the one- and two-blanket attenuation factors for the point-source geometry, which are the exposure rate with the blanket divided by the exposure rate without the blanket.

Table 4: ^{60}Co Point source at 100cm

Angle (degrees)	Exposure rate w/o blanket (μR/h)	Exposure rate with 1 blanket (μR/h)	Exposure rate with 2 blankets (μR/h)	Attenuation Factors	
				1 blanket	2 blankets
10	356±22.3	191±5.1	---	0.54±0.037	---
20	353±29.0	236±17.8	---	0.67±0.074	---
30	359±21.1	278±15.4	---	0.77±0.062	---
90	370±26.3	308±17.6	282±17.0	0.83±0.076	0.76±0.071

Figure 3 shows how the blanket attenuation factors change with angle. The data points in Figure 3 are measured data, and this data was fitted with a curve so interpolations and extrapolations could be estimated.

The minimum dose rate reduction is achieved at an angle of 90 degrees to the floor. This corresponds to a minimum thickness of blanket traversed by the radiation. The measured attenuation factor of 0.83 is higher (i.e. less effective) for ^{60}Co than for ^{137}Cs, as expected, due to the higher energy of the ^{60}Co radiation. Also as expected, the effectiveness of the blanket improves as the angle increases, since there is more material for the radiation to traverse at shallower angles. Doubling the blanket did not affect the exposure rate enough to warrant doing this in practice for a high energy gamma source. It should be noted that exactly how the blanket is folded over on itself could affect the measured results, particularly at small angles. A better test of the effectiveness of doubling the blanket thickness should involve two separate blankets, with which sufficient overlap can be assured.

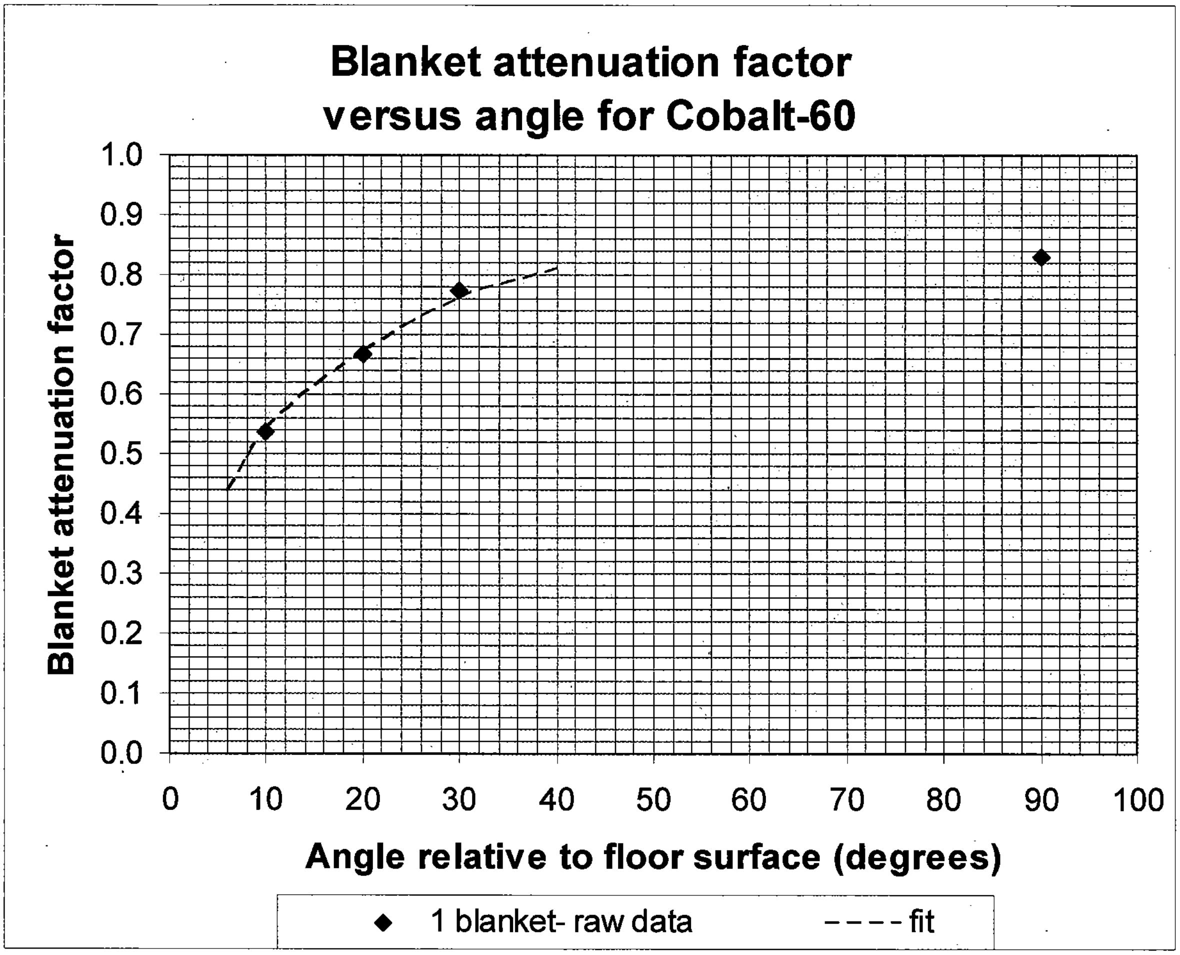

Figure 3: Blanket attenuation factors versus angle for Co-60.

Ra-226 Fields: The test results for ^{226}Ra are provided in Table 5, and include the one- and two-blanket attenuation factors for the point-source geometry.

Table 5: ^{226}Ra Point source at 100cm					
Angle (degrees)	Exposure rate w/o blanket (μR/h)	Exposure rate with 1 blanket (μR/h)	Exposure rate with 2 blankets (μR/h)	Attenuation Factors 1 blanket	2 blankets
10	21000 ± 500	10817±134	5967 ± 98	0.52 ± 0.014	0.28 ± 0.008
20	21000 ± 500	12958 ± 100	8500 ± 74	0.62 ± 0.016	0.4 ± 0.01
30	21000 ± 500	13850 ± 90	9908 ± 100	0.66 ± 0.016	0.47 ± 0.012
90	22000 ± 500	16217 ± 94	13525 ± 148	0.74 ± 0.017	0.61 ± 0.015

Figure 4 shows how the blanket attenuation factors change with angle. Curve fits to the raw data have been added to allow extrapolation and interpolation of the measured data.

The minimum dose rate reduction is achieved at an angle of 90 degrees to the floor. This corresponds to a minimum thickness of blanket traversed by the radiation. The measured attenuation factor of 0.74 is very close to that of ^{137}Cs, as expected, since the average photon energy from ^{226}Ra and its daughters is near that of ^{137}Cs. Also as expected, the effectiveness of the blanket improves as the angle increases, since there is more material for the radiation to traverse at shallower angles. Doubling the blanket thickness further enhanced the effectiveness of the blanket.

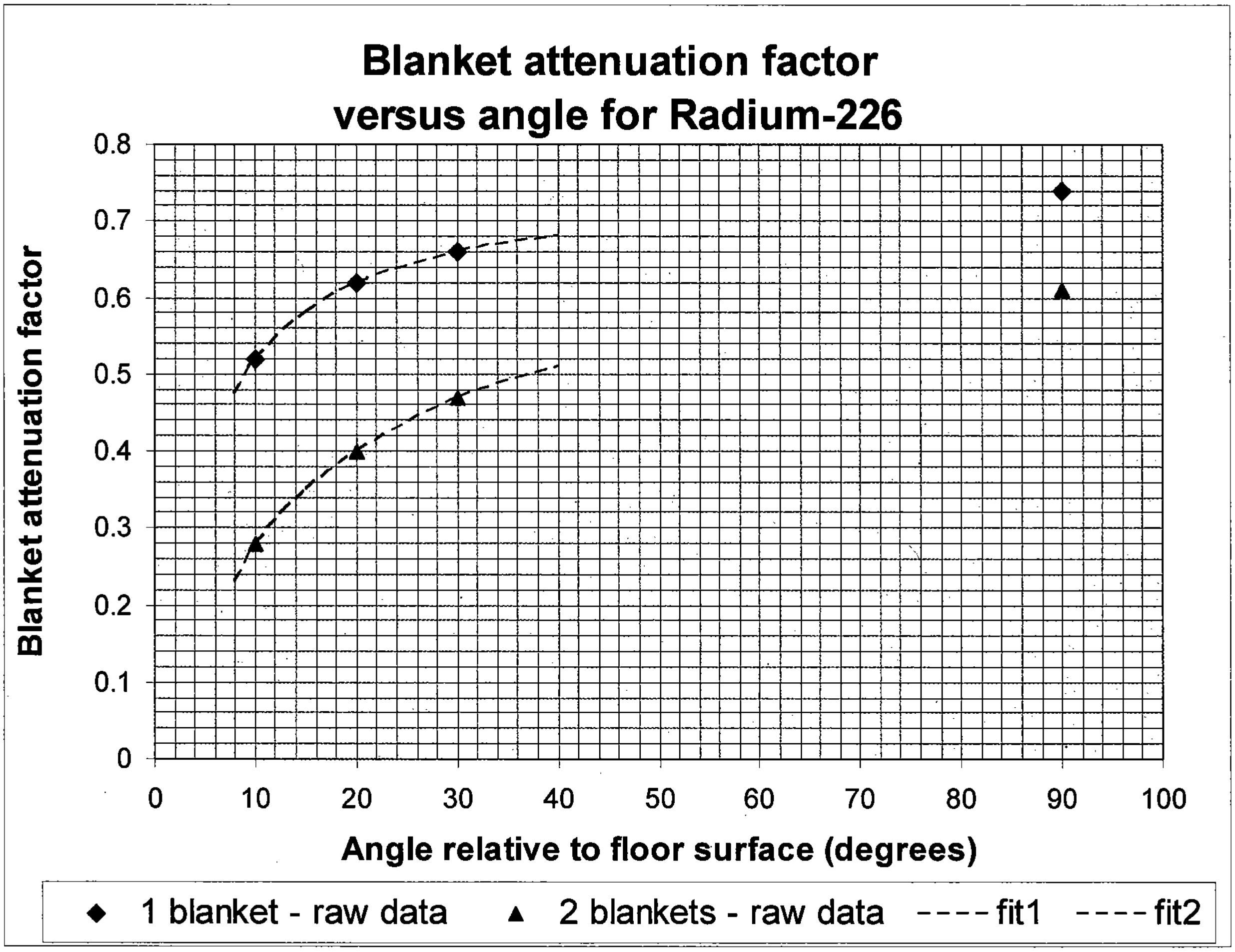

Figure 4: Blanket attenuation factors versus angle for Ra-226.

Figure 5 presents attenuation data obtained at PNNL in January 2003 using sheets of Demron material in a collimated Cs-137 field. Curves for iron and lead have been added to the figure so comparisons can be made. The iron and lead curves are estimates based on data in the third edition of "Handbook of Health Physics and Radiological Health", Williams & Wilkins publishing. Keep in mind that such attenuation data can vary, depending on variations in energy spectrum and size of beam.

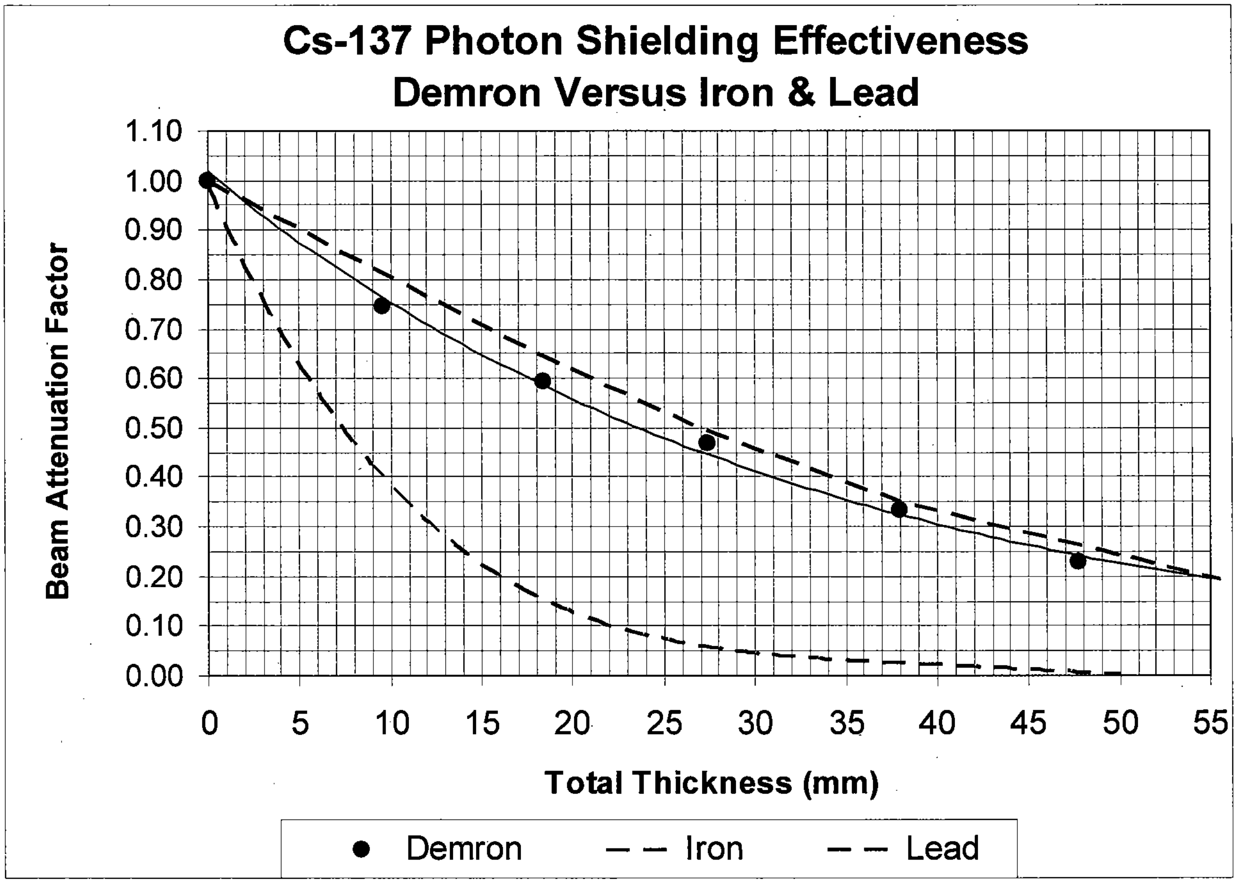

Figure 5: Cs-137 Photon Shielding Effectiveness of Demron Versus Iron & Lead

Conclusions:

The Demron Blanket meets the specifications stated by the manufacturer of an exposure rate reduction of about 30% for ^{137}Cs gamma rays for the 90 degree angle. For angles of approach of 10 to 30 degrees, which are the angles most likely associated with "whole body" dose of the individual, the exposure rate reduction varies from 65% to 39%. The exposure rate falls off as the inverse square of the distance from the midpoint of a source distribution.

As expected, the blanket is less effective at the higher gamma energy of ^{60}Co, achieving a minimum reduction of about 17% at 90 degrees. For angles of approach of 10 to 30 degrees, the exposure rate reduction varies from 46% to 33%.

The blanket is very nearly as effective for ^{226}Ra as it is for ^{137}Cs, achieving a minimum reduction of about 26% at 90 degrees. For angles of approach of 10 to 30 degrees, the exposure rate reduction varies from 48% to 34%.

The point-source versus distributed source data shows that at the distances considered, namely 70 cm and higher, the source is largely indistinguishable from a point source, with a dose rate reduction following the inverse square law. A more uniform distribution of activity may result in the dose rate reduction differing more from the inverse square law.

Data on the effectiveness of the Demron material to attenuate photon fields from 59-662 keV, as well as $^{90}Sr/^{90}Y$ beta fields, can be found in the PNNL report dated January 2003.

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