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September 22, 2004
BYR 2004-103

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Reference: (a) License No. DPR-3 (Docket No. 50-29)

Subject: YNPS Technical Report - Evaluation of Using a Gamma-Only Background Determination for Structures

Pursuant to our discussion on September 8, 2004, this letter provides a copy of a technical report in support of the LTP for the Yankee Nuclear Power Station (YNPS). The specific technical report provided for your review is as follows:

(1) YA-REPT-00-010-04, "Evaluation of Using a Gamma-Only Background Determination for Structures"

If you have any questions, or desire additional information, please contact us.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

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TECHNICAL REPORT TITLE PAGE

Evaluation of Using a Gamma-Only Background Determination for Structures

YA-REPT-00-010-04

Technical Report Number

Approvals	(Print & Sign Name)	
Preparer: Eric Darois	[signature]	Date: 8/11/04
Reviewer: James Hummer	James Hummer	Date: 9/20/04
Approver (Cognizant Manager):	Gregory M. Babineau	Date: 9/21/04

Evaluation of Using a Gamma-Only Background Determination for Structures

1.0 Introduction:

The Yankee Atomic License Termination Plan (Revision 0), proposes to determine the background within a structure by observing a beta sensitive detector response away from a potentially contaminated surface while shielding the detector from beta interactions with sufficient attenuation to attenuate the expected beta particles (i.e., approximately 300 mg/cm^2). This method effectively measures the gamma radiation background from all sources that contribute to the gamma background including that from natural and licensed sources. This evaluation determines the adequacy of this approach for a common GM pancake frisker and for a conservative mixture of radionuclides.

2.0 Analysis Methods

2.1 General Approach

Contamination is assumed to be uniformly distributed over a 10ft X 10ft rectangular surface. From this contamination a gamma exposure rate is calculated at 3 ft from the surface. This exposure rate is converted to a detector response from a gamma energy response curve. The exposure rate is calculated using Microshield™. The beta response of the detector is calculated from a beta response curve (for a 1 cm offset) using the area of the selected detector and the assumed contamination distribution.

2.2 Detector Selection and Energy Response Curves

Several beta-sensitive detectors were considered for this analysis including gas flow proportional, plastic scintillation, and GM. The common GM pancake detector was selected because of the available data on its energy response characteristics. This detector type represents a conservative representation of the other detector types due to its relatively large over-response to low to moderate energy gamma and X-rays. Therefore, the GM pancake detector should result in the highest response to gamma rays originating from all sources.

Reference 5.1 represents a comprehensive analysis of the energy response of a GM pancake detector to both gamma and beta sources. This information is used in this analysis to predict the detector response from the modeled sources. For a given emission from a specified radionuclide, a detector response can be calculated from both beta and gamma emissions separately, then summed for the total response.

For gamma and X-ray emissions, the response for emission energy E, R_γ (cpm) is calculated from the assumed rectangular source as:

$$R_{\gamma,E}(cpm) = R_{\gamma,E}(\tfrac{uR/hr}{uCi/cm^2})GRF_E RF_{Cs\text{-}137} S_A(uCi/cm^2)$$

Equation 1

where:
$R_{\gamma,E}$ is the calculated exposure rate in uR/hr from the modeled geometry for a specific gamma energy E,
GRF(E) is the relative gamma response factor at energy E relative to Cs-137 from Reference 5.1,
$RF_{Cs\text{-}137}$ is the Cs-137 response factor from Reference 5.2, cpm/uR/hr (1 mR/hr = 3600 cpm), and
S_A is the activity distribution modeled from Microshield, 1.0 uCi/cm^2.

For the beta emissions, the response factor is calculated as.

$$R_{\beta,E}(cpm) = 2.22e6\ dpm/uCiA(cm^2) * S_A(uCi/cm^2)Eff_E(c/p)Y_E(p/d)$$

Equation 2

where:
A is the probe area, assumed to be 15 cm^2,
Eff_E is the particle detection efficiency from Reference 5.1, and,
Y_E is the particle emission yield (Reference 5.3).

Equation 1 is applied to calculate the gamma background response of the detector, for each energy emission for the radionuclides under consideration. The sum of equation 1 and 2 is used to calculate the detector response from direct wall measurements. This is a simplifying and conservative approach as the total detector response from the wall uses the gamma response at a distance of 3 feet rather than contact.

2.3 Radionuclide Considerations

For this analysis, four radionuclides are considered; Ag-108m, Co-60, Cs-134, and Cs-137. Although not very abundant at the site, Ag-108m is considered since it is expected to provide additional conservatism since it's beta and electron emissions are low compared to Co-60, Cs-134, and Cs-137. With these four radionuclides, two distributions are considered, a realistic and a conservative. The realistic distribution is based on recent waste stream samples and sampling of concrete cores in the Spent Fuel Pool (SFP) and the Ion Exchange Pit (IXP). The conservative distribution is based on Ag-108m at 5% and equal abundances of Co-60, Cs-134, and Cs-137 making up the remainder.

3.0 Results and Discussions

Table 1 provides the emission data and results of the calculated response from each emission and for each radionuclide under consideration.

Table 1
Summary Of Calculated Detector Responses For A Contamination Level Of 1 uCi/cm²

Nuclide	Emission Type	Emission Energy, MeV	Yield	[1]Gamma Exposure Rate for 1uCi/cm², mR/hr	Relative Response or Efficiency[2]	Detector Response, cpm
Ag-108m	Gamma	0.030	0.000	8.60E-07	3.50	1.08E-02
	Gamma	0.025	0.656	5.10E+00	3.15	5.78E+04
	Gamma	0.079	0.071	1.26E-01	3.05	1.38E+03
	Gamma	0.434	0.899	1.06E+01	0.80	3.05E+04
	Gamma	0.614	0.904	1.50E+01	1.00	5.39E+04
	Gamma	0.723	0.905	1.74E+01	1.00	6.27E+04
					Total	2.06E+05
	Electron	0.699	0.002	N/A	0.241	1.38E+04
	Electron	0.075	0.002	N/A	0.000	0.00E+00
	Electron	0.005	0.002	N/A	0.000	0.00E+00
	Electron	0.590	0.003	N/A	0.219	1.92E+04
	Electron	0.019	0.004	N/A	0.000	0.00E+00
	Electron	0.410	0.007	N/A	0.171	4.02E+04
					Total	7.33E+04
Co-60	Gamma	1.173	1.000	29.00	1	1.04E+05
	Gamma	1.333	1.000	31.97	1	1.15E+05
					Total	2.20E+05
	Beta	0.3179	1.000	N/A	0.137	4.57E+06
					Total	4.57E+06
Cs-137	Gamma[3]	0.036	0.013	3.84E-01	3.70	9.70E+02
		0.032	0.020	7.28E-02	3.70	1.74E+03
		0.032	0.036	1.31E-01	4.20	5.81E+02
		0.662	0.851	1.51E+01	1.00	5.44E+04
					Total	5.77E+04
	Electron[3]	0.660	0.005	N/A	0.234	3.53E+04
		0.026	0.008	N/A	0.000	0.00E+00
		0.656	0.014	N/A	0.233	1.07E+05
		0.004	0.072	N/A	0.000	0.00E+00
		0.624	0.076	N/A	0.226	5.76E+05
					Total	7.18E+05
	Beta	1.173	0.054	N/A	0.309	5.56E+05
		0.512	0.946	N/A	0.200	6.30E+06
					Total	6.85E+06
					Total Beta/Electron	7.57E+06
Cs-134	Gamma	0.004	0.001	0.000	0.015	0.00E+00
		0.032	0.002	0.008	3.8	1.09E+02

Nuclide	Emission Type	Emission Energy, MeV	Yield	[1]Gamma Exposure Rate for 1uCi/cm[2], mR/hr	Relative Response or Efficiency[2]	Detector Response, cpm
		0.032	0.004	0.014	3.8	1.97E+02
		0.036	0.001	0.004	4.2	6.37E+01
		0.277	0.000	0.003	0.9	8.26E+00
		0.475	0.015	0.189	0.9	6.12E+02
		0.563	0.084	1.280	1	4.61E+03
		0.569	0.154	2.380	1	8.57E+03
		0.605	0.976	15.900	1	5.72E+04
		0.796	0.854	17.900	1	6.44E+04
		0.802	0.087	1.840	1	6.62E+03
		1.039	0.010	0.263	1	9.47E+02
		1.168	0.018	0.520	1	1.87E+03
		1.365	0.030	0.990	1	3.56E+03
					Total	1.49E+05
	Electron	0.004	0.007	N/A	0.000	0.00E+00
		0.026	0.001	N/A	0.000	0.00E+00
		0.532	0.001	N/A	0.205	8.56E+03
		0.567	0.005	N/A	0.214	3.49E+04
		0.758	0.002	N/A	0.252	1.85E+04
					Total	6.19E+04
	Beta	0.089	0.274	N/A	0.000	0.00E+00
		0.415	0.025	N/A	0.172	1.42E+05
		0.658	0.701	N/A	0.233	5.44E+06
		0.976	0.001	N/A	0.285	5.03E+03
					Total	5.59E+06
					Total Beta/Electron	5.65E+06

1 Values calculated from Microshield.
2 Values from Reference 5.1. Relative response values are relative to Cs-137.
3 Includes Emissions from Ba-137m

As noted from the response values in Table 1, the gamma response fraction for Ag-108m is approximately 74% of the total response compared to that of Co-60, Cs-137, and Cs-134 of 4.6%, 0.8%, and 2.6% respectively.

Table 2 provides a summary of recent waste and contamination characterization data from the site. As shown in this data, the predominance of Ag-108m is less than 5% in all cases. However, for a conservative analysis of the detector response from a contaminated wall whereby the gamma (or background) response is maximized, the Ag-108m activity fraction will be set at 0.05, and the remaining fractions divided evenly at 0.317 each.

Table 2: Summary of Nuclide Fraction from Characterization of Various Sources.

	Nuclide Fractions			
	Co-60	Cs-137	Cs-134	Ag-108m
TK-81 Tank Sludge	0.983	0.016	0	0.001
TK38-41 Tank Sludge	0.887	0.104	0	0.008
VC Composite Smear	0.23	0.767	0.003	0
WDB Composite Smear	0.719	0.238	0	0.043
PAB Composite Smear	0.481	0.498	0	0.021
SFP Core	0.0635	0.9359	0.0003	0.0003
IXP Core	0.0425	0.955	0.0024	0
Average	0.487	0.502	0.0081	0.010
STDEV	0.388	0.393	0.001	0.016

Table 3 provides a summary of the conservative analysis of the detector response from the radionuclide distribution where the Ag-108m fraction is 0.05. The values in Table 3 (as well as Table 4) are derived as follows.

- For the "room" response;
  The response from the gamma emissions for each nuclide, scaled to the contamination levels shown in Table 3.
- For the "wall" response;
  The "room" response value added to the sum of the responses from the electron and beta emissions scaled to the contamination levels in Table 3.

In this case, the contamination level of Ag-108m is 1406 dpm/100 cm^2 and for each of the other radionuclides, 8908 dpm/100 cm^2. This level corresponds to a fractional sum of 1.0 DCGL.

The results of this conservative analysis indicate that the room response, or gamma response from three feet from the wall surface, is 2.5 % of the response from the case where the detector is on the wall.

Table 3: Summary of Conservative Response

Nuclide	Concentration dpm/100cm^2	DCGL, dpm/100cm^2	DCGL Fraction	Detector Response, cpm Room	Detector Response, cpm Wall
Ag-108m	1406	25000	5.62E-02	1.31E+00	1.77E+00
Cs-137	8908	63000	1.41E-01	2.31E+00	3.06E+02
Cs-134	8908	29000	3.07E-01	5.97E+00	2.33E+02
Co-60	8908	18000	4.95E-01	8.81E+00	1.92E+02
		Total =	1.00E+00	1.84E+01	7.33E+02

A realistic analysis of the response to a contaminated wall is provided from the data contained in Table 2. This contamination profile represents the mixture of nuclides expected on surfaces at the time of final status surveys.

In this case, the Ag-108m fraction is 0.01, the Cs-137 fraction is 0.502, the Cs-134 fraction is 0.008, and the Co-60 fraction is 0.49. These nuclide fractions are taken from Table 2. As indicated in Table 4, the gamma response from the contaminated wall is approximately 2.24% of the detector response from direct measurement of the wall. This indicates a smaller but similar contribution to background as in the case of the conservative nuclide distribution. This similar value results from the similar fractions of Co-60 and Cs-137 as these nuclides dominate the detector responses for the "wall" case.

Table 4: Summary of Realistic Response

Nuclide	Concentration	DCGL, dpm/100cm2	DCGL Fraction	Detector Response, cpm Room	Detector Response, cpm Wall
Ag-108m	295	25000	1.18E-02	2.75E-01	3.72E-01
Cs-137	14162	63000	2.25E-01	3.68E+00	4.87E+02
Cs-134	23	29000	7.92E-04	1.54E-02	6.00E-01
Co-60	13727	18000	7.63E-01	1.36E+01	2.96E+02
			1.00E+00	1.75E+01	7.84E+02

Additionally, conservatism is included in this analysis since the gamma response for the detector on the wall is assumed to be identical to the response at three feet. In fact, it would be expected that the gamma response would increase by at least a factor of 5 for the case where the detector is in contact with the wall. Since this effect has not been included, the overall contribution of the gamma response when the detector is in contact with the wall has been under-stated.

4.0 Conclusions and Recommendations

This conservative analysis shows that the expected gamma response at three feet from a 10 ft X 10 ft wall contaminated at 1.0 DCGL is approximately 2.5% of the detector response with the detector directly on the wall. This shows that background measurements may be taken at 3 or more feet from a wall to be beta surveyed with virtually no impact on the beta measurements when these values are subtracted from the beta measurements on the wall surface.

It is recommended that multiple background readings be taken in a given building which can be averaged.

5.0 References

5.1 "GM Pancake Detectors: Everything You Wanted To Know (But Were Afraid to Ask)". Paul Steinmeyer: RSO Magazine, January/February 1996.

5.2 Thermo specification for HP-210 detector probe.

5.3 Radiation Decay Version 3, Charles Hacker, Griffith University. (Data Tables from "Radioactive Decay Tables", David C. Kocher, Report DOE/TIC-11026.