GPU NUCLEAR

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E910-02-025
May 22, 2002

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Subject: Saxton Nuclear Experimental Corporation (SNEC)
Operating License No., DPR-4
Docket No. 50-146
Submittal of Information to NRC in April 8, 2002 and May 8, 2002 Meetings

Gentlemen,

Two meetings between NRC and GPU Nuclear, Inc. were held in Rockville, Md. The intent of the meetings was to discuss SNEC's License Termination Plan (LTP), dose modeling and characterization issues addressed in NRC's requests for additional information. This letter summarizes the information that was provided to the NRC in these meetings.

Reference NRC Letter dated March 28, 2002, Subject: "Saxton Nuclear Experimental Facility – Discussion Topics for April 8, 2002 Meeting (TAC No. MA8076)"

During this meeting GPU Nuclear, Inc. provided the following:

1. K_d Report titled – "K_d Study of Site Soils and Construction Debris from the SNEC Decommissioning Project," Argonne National Laboratory, February 2002.
2. SNEC Calculation E900-01-005, "Determination of Surface Area Factors," April 5, 2002.
3. CD-ROM RESRAD 6.1 Dose Model Files for SNEC Surface Model.
4. CD-ROM RESRAD 6.1 Dose Model Files for SNEC Subsurface Model and also final URS report.
5. Presentation handouts addressing the above referenced NRC letter.

Reference NRC Letter dated May 1, 2002, Subject: "Saxton Nuclear Experimental Facility – Discussion Topics for May 8, 2002 Meeting (TAC No. MA8076)"

During this meeting GPU Nuclear, Inc. provided the following:

1. Report titled – "Embedded Pipe Radiation Survey Report," Cophysics Corp. January 2002.

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2. SNEC Calculation E900-01-030, Revision1, "SNEC Radionuclide List," April 30, 2002.
3. Table of RESRAD Input Values for SNEC surface model.
4. Presentation handouts addressing the above referenced NRC letter.

If you have any questions concerning this information please contact Mr. James Byrne at (717) 948-8461.

Sincerely,

G. A. Kuehn
Program Director, SNEC

cc: NRC Project Manager
NRC Project Scientist, Region 1

GPU NUCLEAR

Calculation Sheet

Subject	Calc. No.	Rev. No.	Sheet No.
Determination of Surface Area Factors	E900-01-005	0	_1__of_1

Originator	Date	Reviewed by	Date
Pat Donnachie	April 5, 2002	Art Paynter	5 April 02

1. Purpose

Determine surface area factors in support of the SNEC License Termination Plan (LTP).

2. Summary of results

Summary results of the applicable computer runs, input data and supporting information are attached. See Section 5 below for specific tables and graphs.

3. References:

1. RESRAD-BUILD Version 3.0
2. DandD Version 1.0

4. Assumptions and Basic Data

Surface area factors have been developed using comparative analyses between DandD, 1.0 and RESRAD-BUILD, 3.0. These area factors will be used to develop $DCGL_{EMC}$ screening values for residual radioactivity on building surfaces. DandD surface area screening values from the SNEC LTP were used as inputs into the RESRAD-BUILD, 3.0 program to determine the annual default dose at 36 m^2. This dose was then used to ratio against doses calculated for 25, 16, 9, 4, and 1 m^2 areas. The calculated ratio is equal to the area factor value for the respective area sizes. The surface area DCGL can be multiplied by the derived area factor to determine the $DCGL_{EMC}$.

5. **Calculation**

Hard copies of the summary tables and derived graphs are attached. 25 mrem/yr surface screening values (dpm/100 cm^2) for 26 nuclides were converted to pCi/m^2 and entered as input into the RESRAD-BUILD program. The calculated RESRAD-BUILD dose at 36 m^2 was then compared to doses derived for smaller areas (i.e. 1, 4, 9, 16, & 25 m^2) to determine area factors. Graphs have also been developed to display the lin-log nature of the data.

Table 1 - Calculation Sheet for SNEC Surface Area Factors and $DCGL_{EMC}$ Development.
Table 2 - SNEC Surface Area Factors for $DCGL_{EMC}$.

Appendix A - Area Factor Graphs for 26 Nuclides

Table 1

Calculation Sheet for SNEC Surface Area Factors and $DCGL_{EMC}$ Development

DR = RESRADBLD Dose Rate (mrem/year) for Area x.
AF = Area Factor for Area x

	25 mrem/yr Screening Values		DR@36 m²	DR@25	AF 25 m²	DR@16	AF 16 m²	DR@9	AF 9 m²	DR@4	AF 4 m²	DR@1	AF 1 m²
	DandD	RESRADBLD											
Nuclide	dpm/100cm²	pCi/m²											
Am-241	2.70E+01	1.22E+03	5.07	3.45	1.5	2.21	2.3	1.24	4.1	0.55	9.2	0.14	36.2
C-14	3.70E+06	1.67E+08	11.50	8.02	1.4	5.14	2.2	2.90	4.0	1.29	8.9	0.32	35.9
Cm-243	3.90E+01	1.76E+03	4.78	3.32	1.4	2.12	2.3	1.19	4.0	0.53	9.0	0.13	36.8
Cm-244	4.90E+01	2.21E+03	4.74	3.29	1.4	2.11	2.2	1.18	4.0	0.53	8.9	0.13	36.5
Co-60	7.00E+03	3.15E+05	8.21	6.95	1.2	5.59	1.5	4.09	2.0	2.44	3.4	0.81	10.1
Cs-134	1.30E+04	5.86E+05	9.01	7.63	1.2	6.14	1.5	4.50	2.0	2.70	3.3	0.89	10.1
Cs-137	2.80E+04	1.26E+06	9.38	7.74	1.2	6.08	1.5	4.36	2.2	2.55	3.7	0.84	11.2
Eu-152	1.30E+04	5.86E+05	8.10	6.76	1.2	5.37	1.5	3.89	2.1	2.30	3.5	0.76	10.7
Eu-154	1.10E+04	4.95E+05	7.40	6.15	1.2	4.87	1.5	3.51	2.1	2.10	3.5	0.68	10.9
Eu-155	1.60E+05	7.21E+06	6.50	5.21	1.2	3.95	1.6	2.73	2.4	1.54	4.2	0.49	13.3
Fe-55	4.50E+06	2.03E+08	5.38	3.74	1.4	2.39	2.3	1.35	4.0	0.60	9.0	0.15	35.9
H-3	1.20E+08	5.41E+09	11.80	8.23	1.4	5.26	2.2	2.96	4.0	1.32	8.9	0.33	35.8
Nb-94	8.30E+03	3.74E+05	7.74	6.40	1.2	5.04	1.5	3.61	2.1	2.12	3.7	0.69	11.2
Ni-59	4.20E+06	1.89E+08	5.54	3.85	1.4	2.46	2.3	1.38	4.0	0.61	9.1	0.15	36.9
Ni-63	1.80E+06	8.11E+07	5.64	3.92	1.4	2.51	2.2	1.41	4.0	0.63	9.0	0.16	35.3
Pu-238	3.00E+01	1.35E+03	4.80	3.33	1.4	2.13	2.3	1.20	4.0	0.53	9.1	0.13	36.9
Pu-239	2.80E+01	1.26E+03	4.96	3.45	1.4	2.21	2.2	1.24	4.0	0.55	9.0	0.14	35.4
Pu-240	2.80E+01	1.26E+03	4.96	3.45	1.4	2.21	2.2	1.24	4.0	0.55	9.0	0.14	35.4
Pu-241	8.80E+02	3.96E+04	2.78	1.93	1.4	1.24	2.2	0.70	4.0	0.31	9.0	0.08	34.8
Pu-242	2.90E+01	1.31E+03	4.94	3.43	1.4	2.20	2.2	1.24	4.0	0.55	9.0	0.14	35.3
Sb-125	4.40E+04	1.98E+06	8.60	7.40	1.2	6.00	1.4	4.43	1.9	2.66	3.2	0.89	9.7
Sr-90	8.70E+03	3.92E+05	5.90	4.11	1.4	2.64	2.2	1.50	3.9	0.67	8.8	0.17	34.7
Tc-99	1.30E+06	5.86E+07	6.50	4.51	1.4	2.89	2.2	1.63	4.0	0.73	8.9	0.18	36.1
U-234	9.00E+01	4.05E+03	4.83	3.35	1.4	2.15	2.2	1.21	4.0	0.54	8.9	0.13	37.2
U-235	9.10E+01	4.10E+03	4.56	3.17	1.4	2.03	2.2	1.14	4.0	0.51	8.9	0.13	35.1
U-238	1.00E+02	4.50E+03	4.80	3.33	1.4	2.13	2.3	1.20	4.0	0.53	9.1	0.13	36.9

1 dpm/100cm² = 45.045 pCi/m²

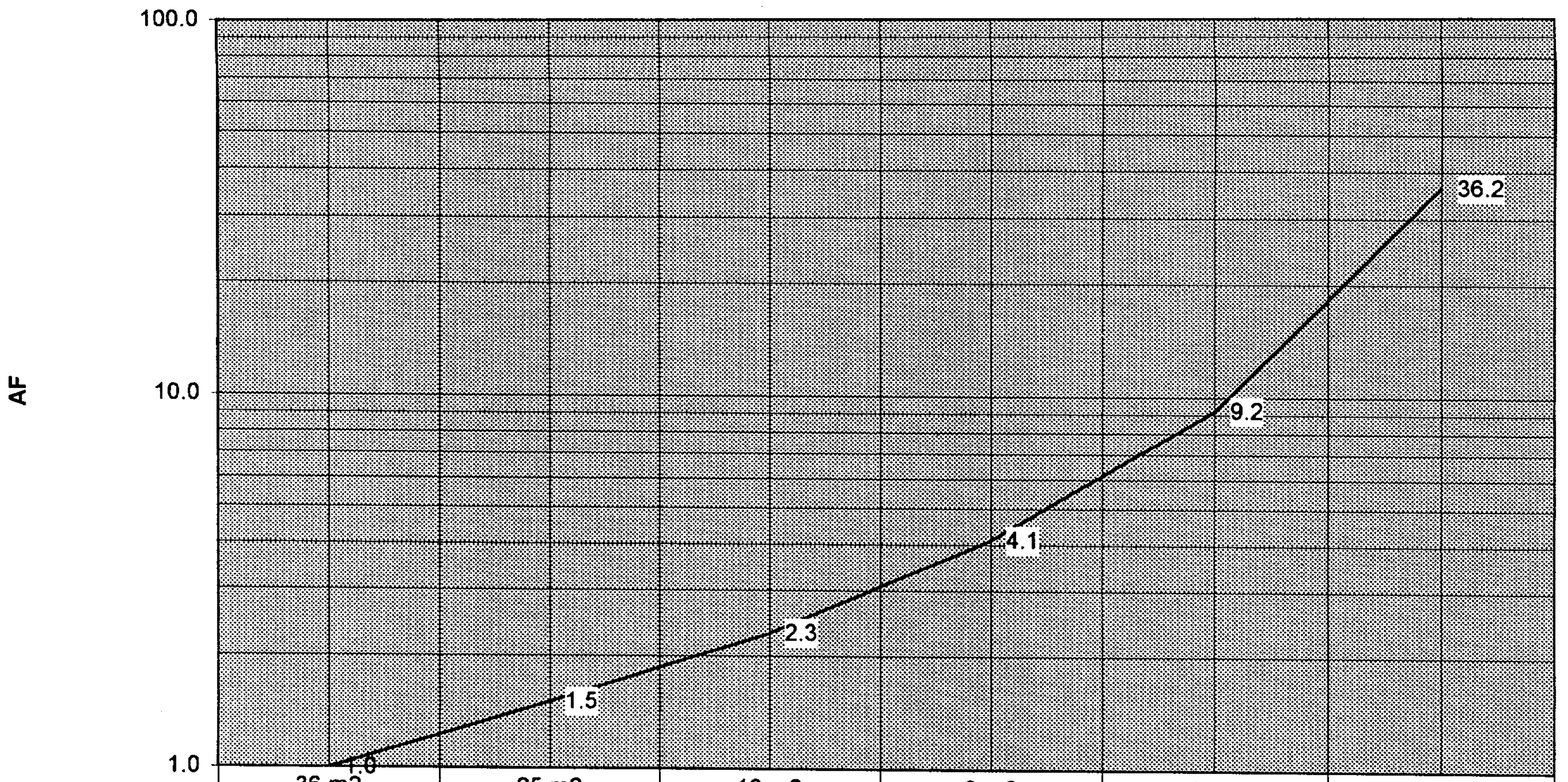
W/SNEC/SNEC EMC.XLS

Table 2

SNEC Surface Area Factors for $DCGL_{EMC}$

Nuclide	36 m²	25 m²	16 m²	9 m²	4 m²	1 m²
Am-241	1.0	1.5	2.3	4.1	9.2	36.2
C-14	1.0	1.4	2.2	4.0	8.9	35.9
Cm-243	1.0	1.4	2.3	4.0	9.0	36.8
Cm-244	1.0	1.4	2.2	4.0	8.9	36.5
Co-60	1.0	1.2	1.5	2.0	3.4	10.1
Cs-134	1.0	1.2	1.5	2.0	3.3	10.1
Cs-137	1.0	1.2	1.5	2.2	3.7	11.2
Eu-152	1.0	1.2	1.5	2.1	3.5	10.7
Eu-154	1.0	1.2	1.5	2.1	3.5	10.9
Eu-155	1.0	1.2	1.6	2.4	4.2	13.3
Fe-55	1.0	1.4	2.3	4.0	9.0	35.9
H-3	1.0	1.4	2.2	4.0	8.9	35.8
Nb-94	1.0	1.2	1.5	2.1	3.7	11.2
Ni-59	1.0	1.4	2.3	4.0	9.1	36.9
Ni-63	1.0	1.4	2.2	4.0	9.0	35.3
Pu-238	1.0	1.4	2.3	4.0	9.1	36.9
Pu-239	1.0	1.4	2.2	4.0	9.0	35.4
Pu-240	1.0	1.4	2.2	4.0	9.0	35.4
Pu-241	1.0	1.4	2.2	4.0	9.0	34.8
Pu-242	1.0	1.4	2.2	4.0	9.0	35.3
Sb-125	1.0	1.2	1.4	1.9	3.2	9.7
Sr-90	1.0	1.4	2.2	3.9	8.8	34.7
Tc-99	1.0	1.4	2.2	4.0	8.9	36.1
U-234	1.0	1.4	2.2	4.0	8.9	37.2
U-235	1.0	1.4	2.2	4.0	8.9	35.1
U-238	1.0	1.4	2.3	4.0	9.1	36.9

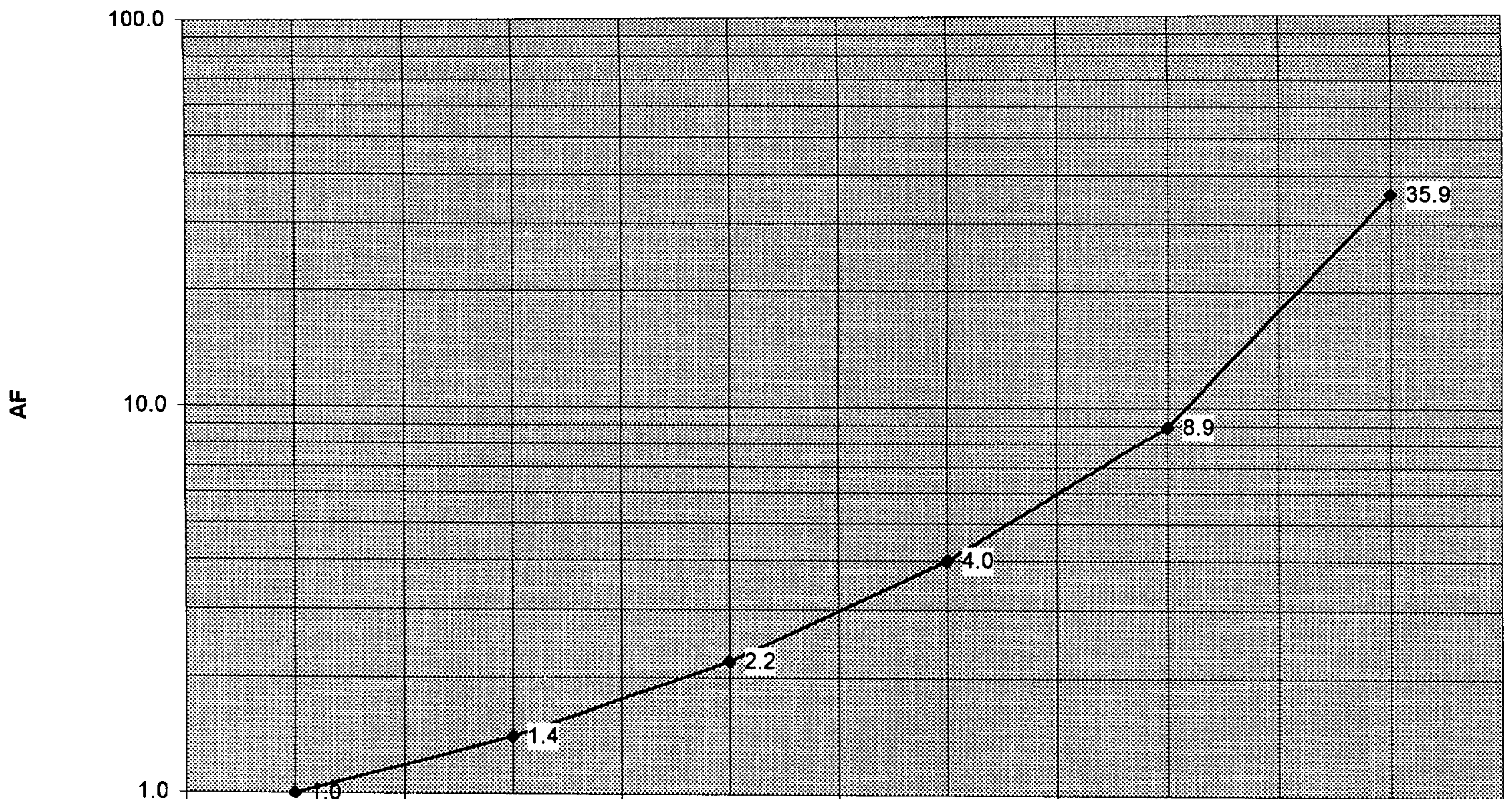
Am241 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Am241 AF	1.0	1.5	2.3	4.1	9.2	36.2

Area Size

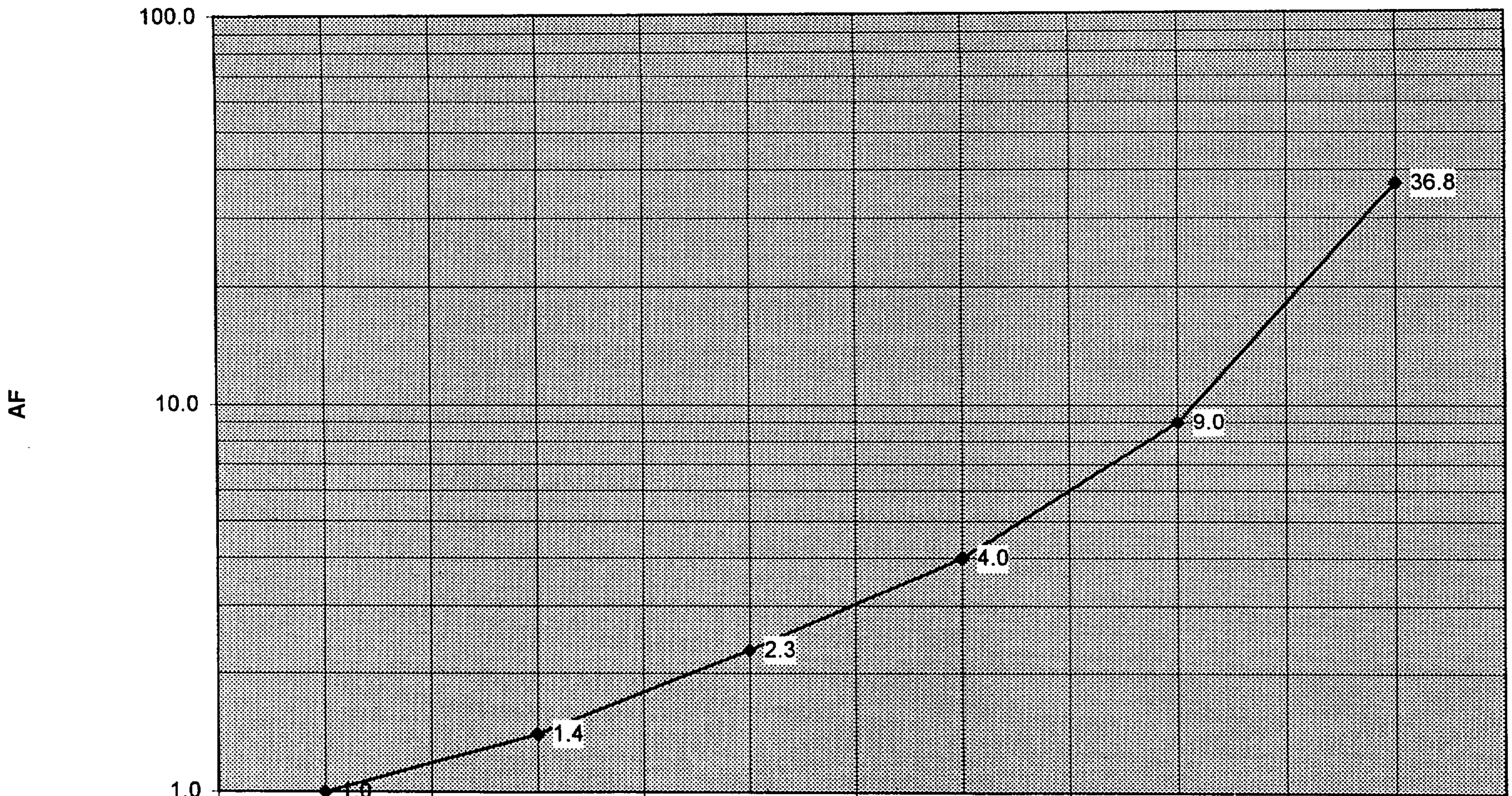
C14 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
C14 AF	1.0	1.4	2.2	4.0	8.9	35.9

Area Size

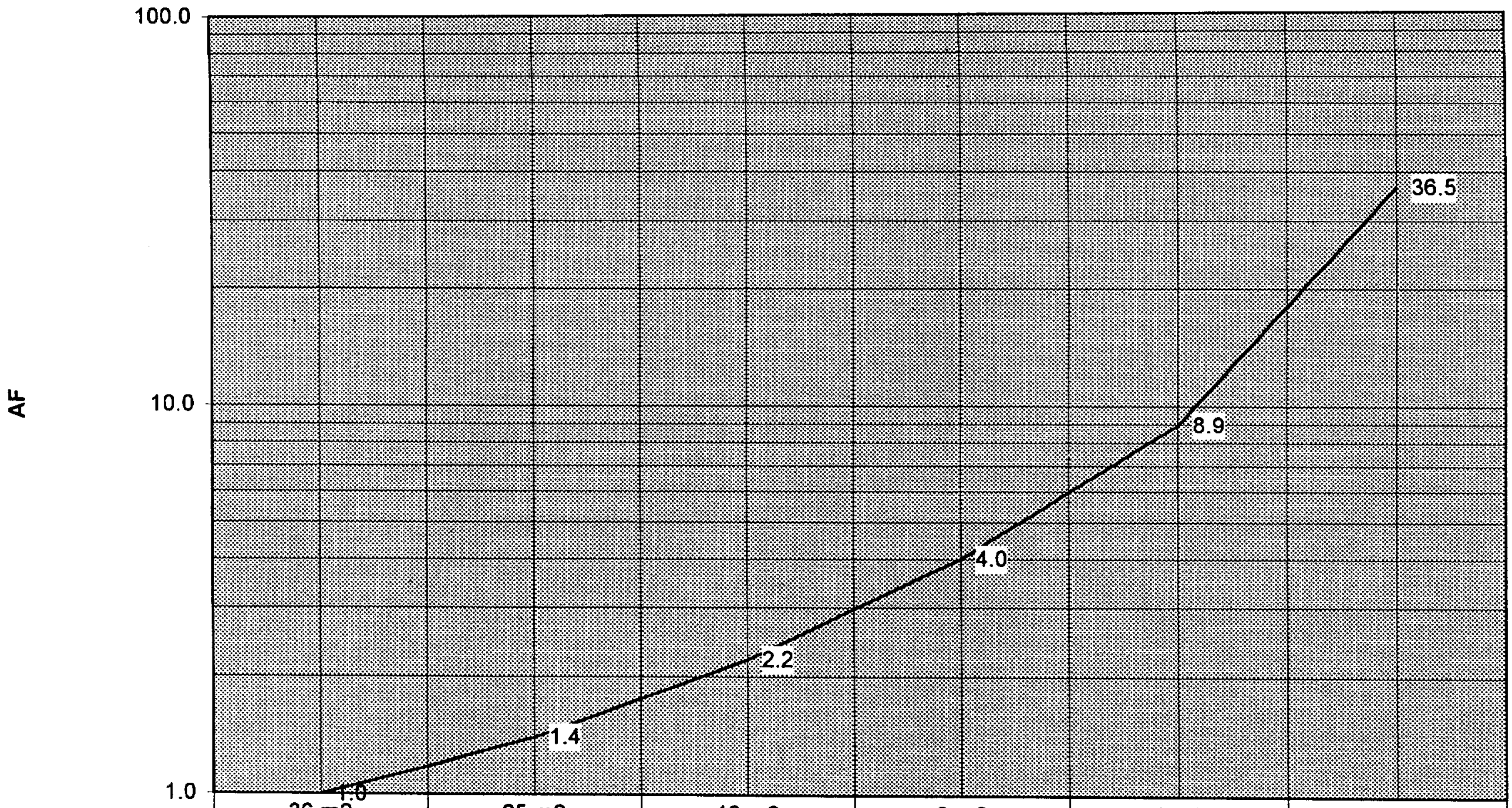
Cm243 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Cm243 AF	1.0	1.4	2.3	4.0	9.0	36.8

Area Size

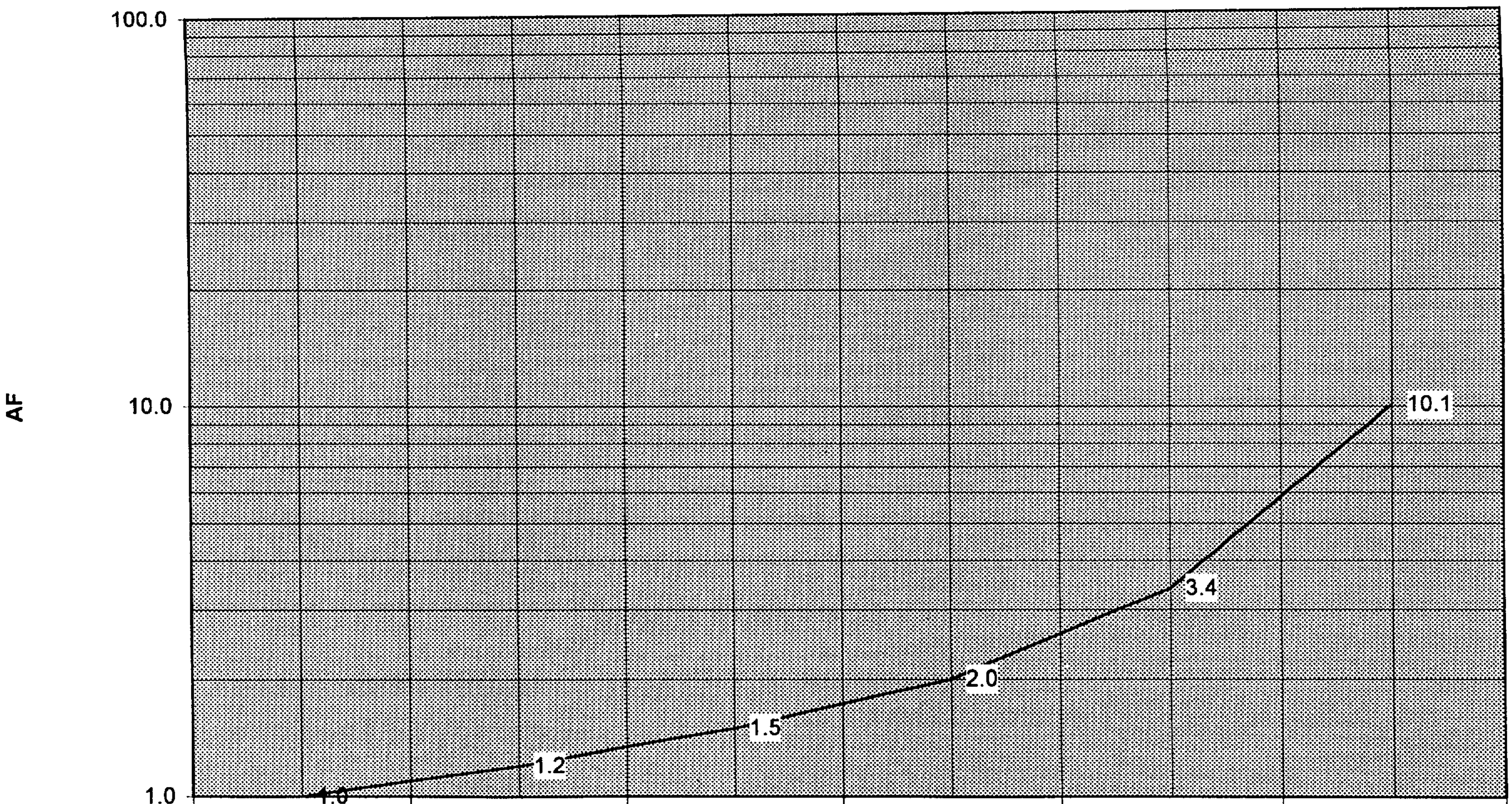
Cm244 Area Factos



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Cm244 AF	1.0	1.4	2.2	4.0	8.9	36.5

Area Size

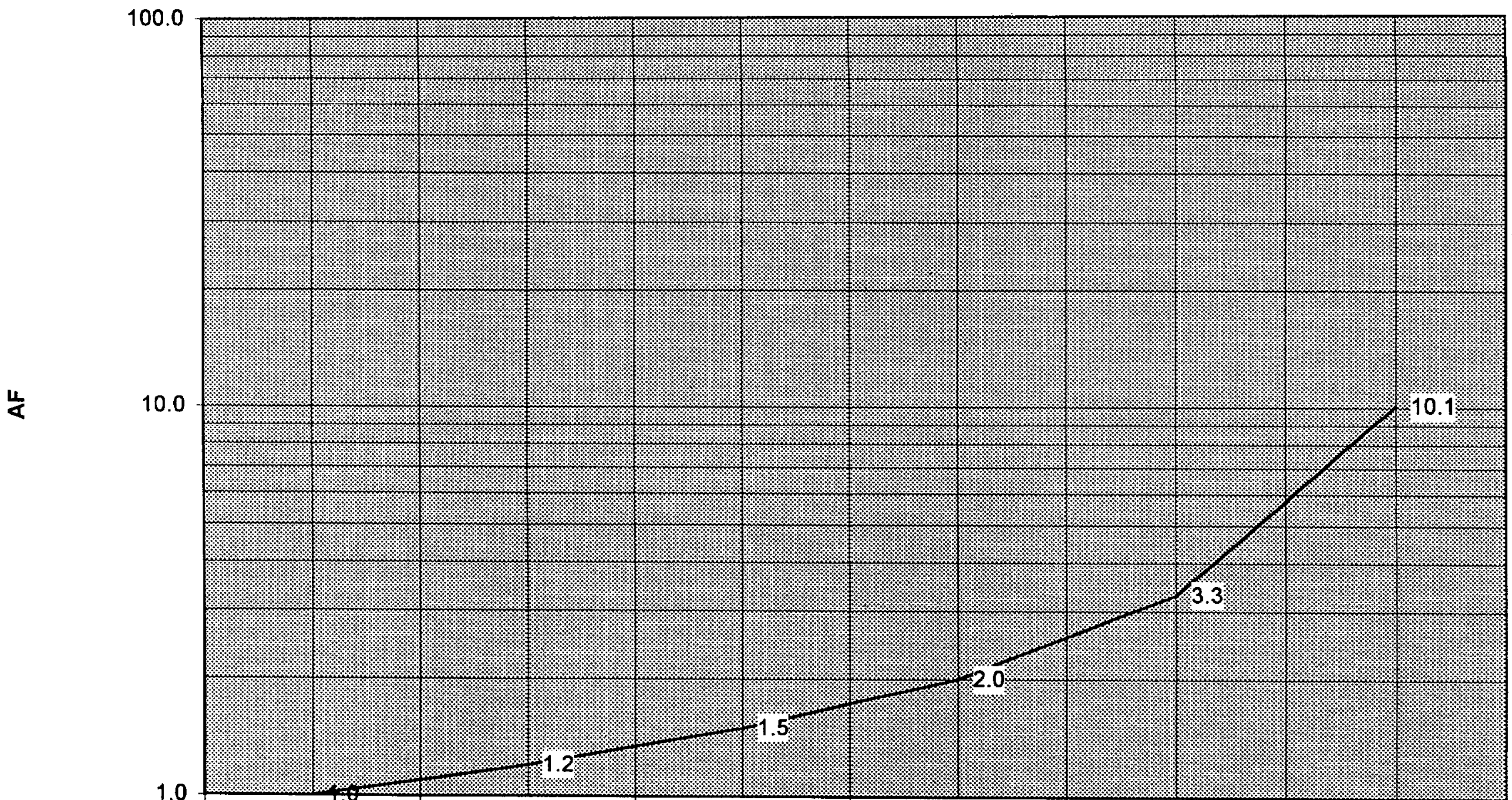
Co60 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Co60 AF	1.0	1.2	1.5	2.0	3.4	10.1

Area Size

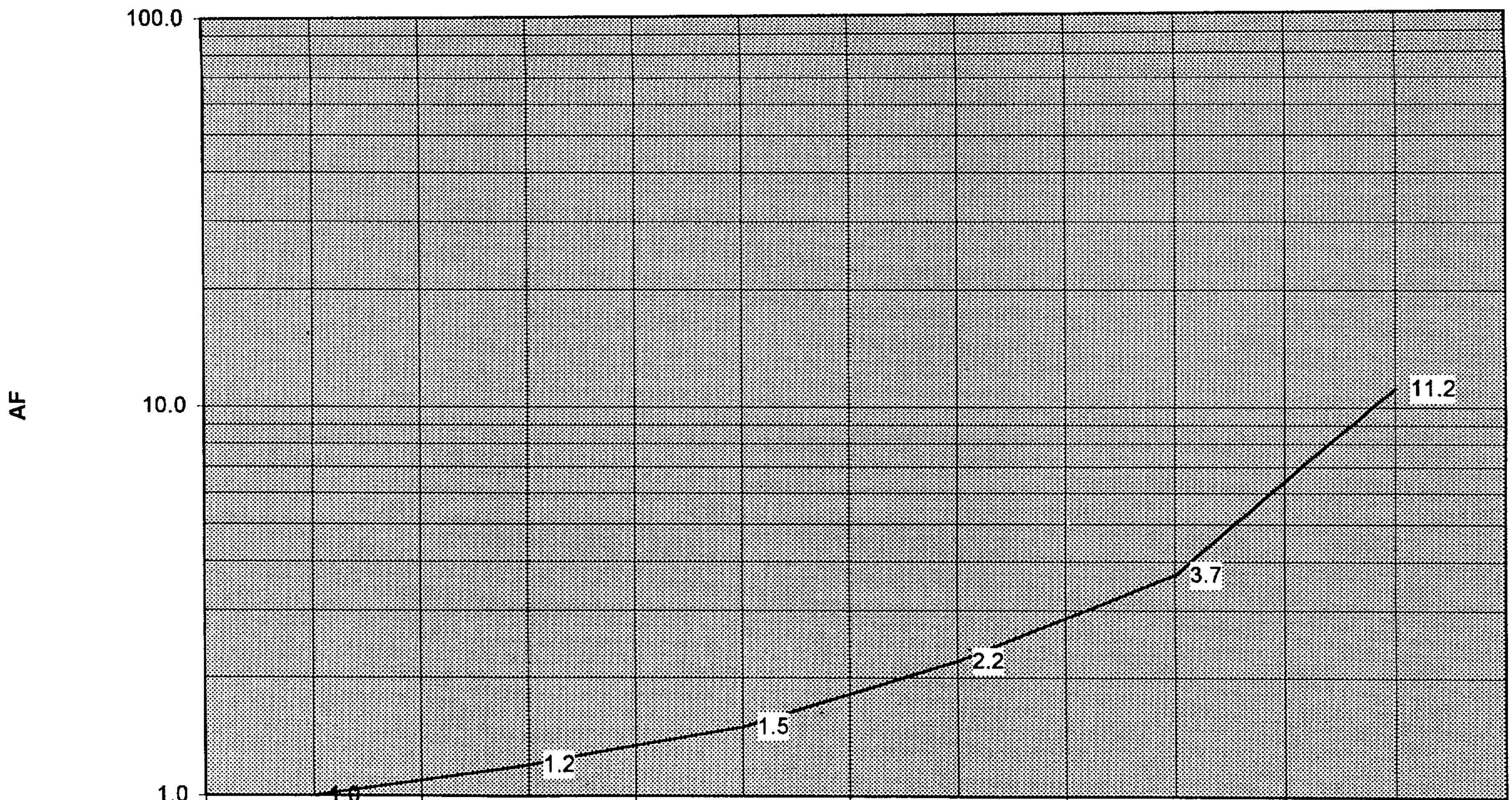
Cs134 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Cs134 AF	1.0	1.2	1.5	2.0	3.3	10.1

Area Size

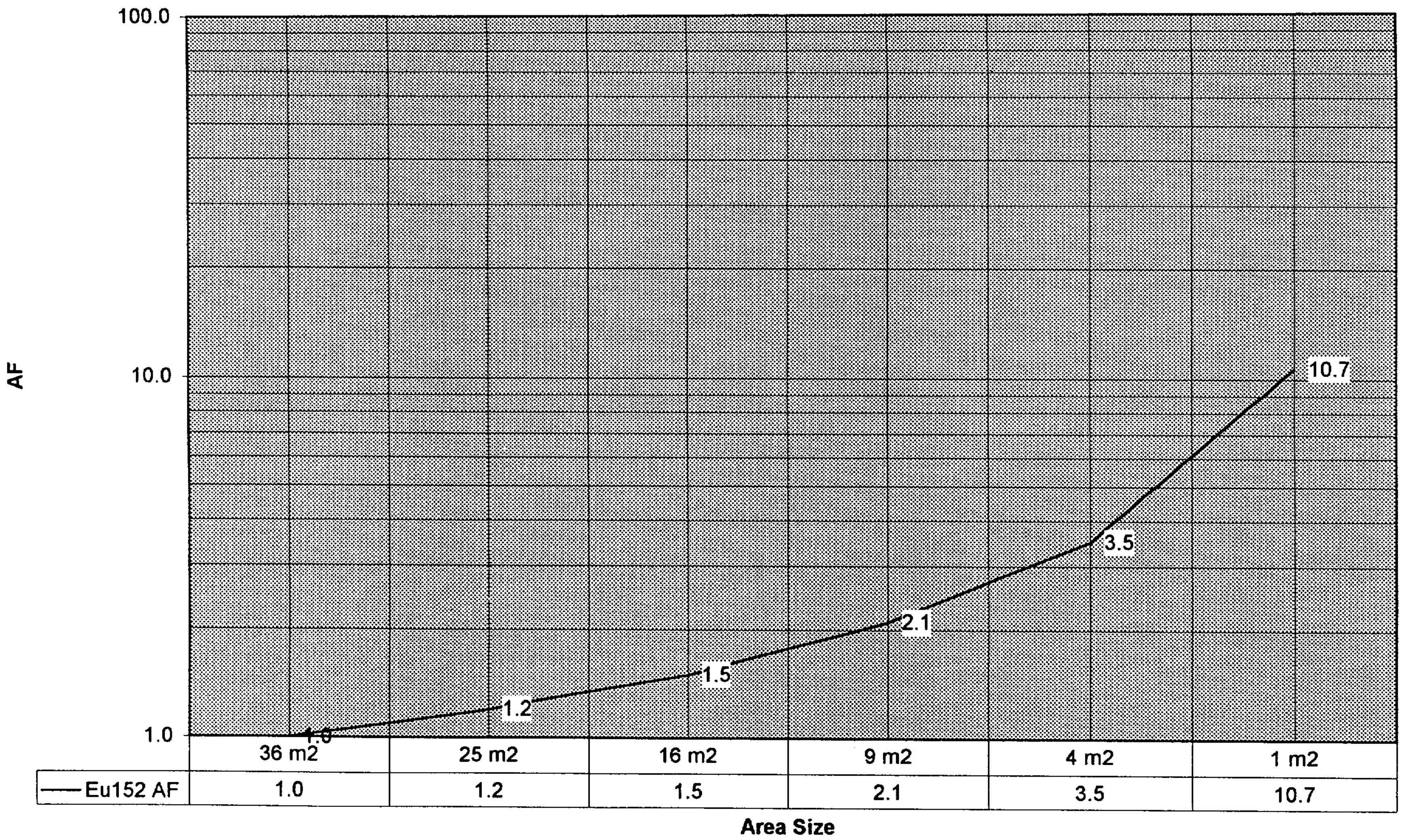
Cs137 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Cs137 AF	1.0	1.2	1.5	2.2	3.7	11.2

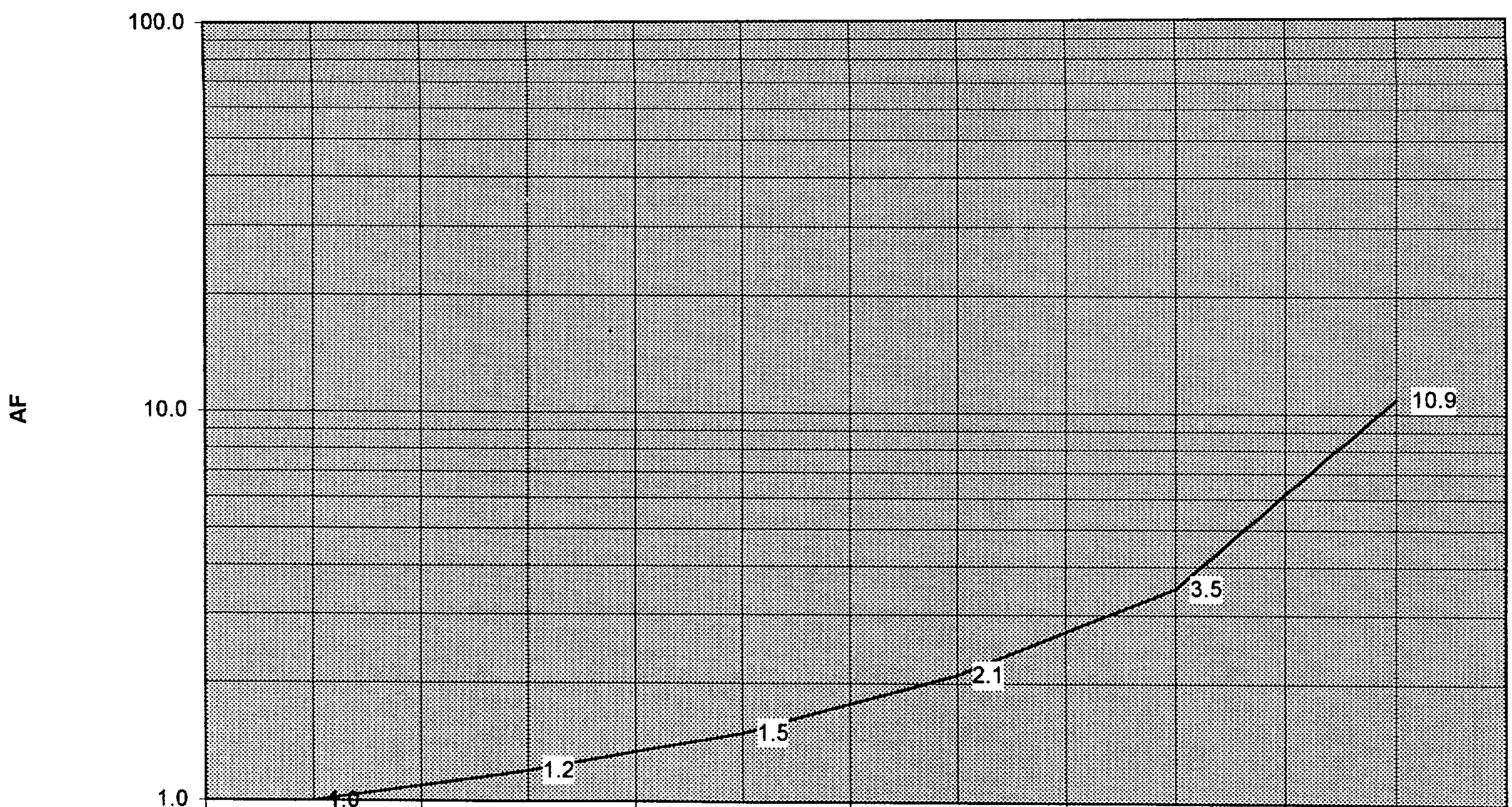
Area Size

Eu152 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Eu152 AF	1.0	1.2	1.5	2.1	3.5	10.7

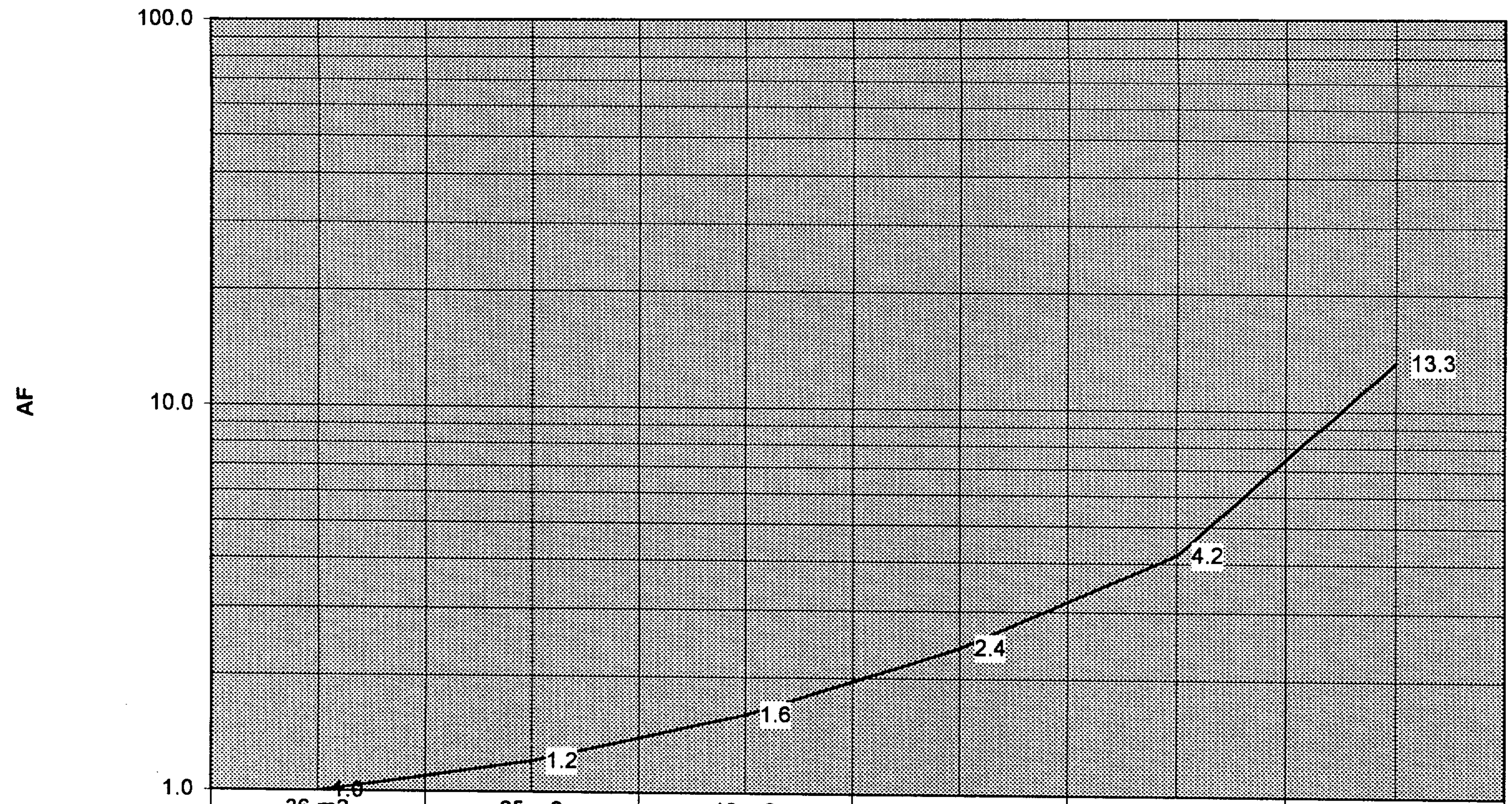
Eu154 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Eu154 AF	1.0	1.2	1.5	2.1	3.5	10.9

Area Size

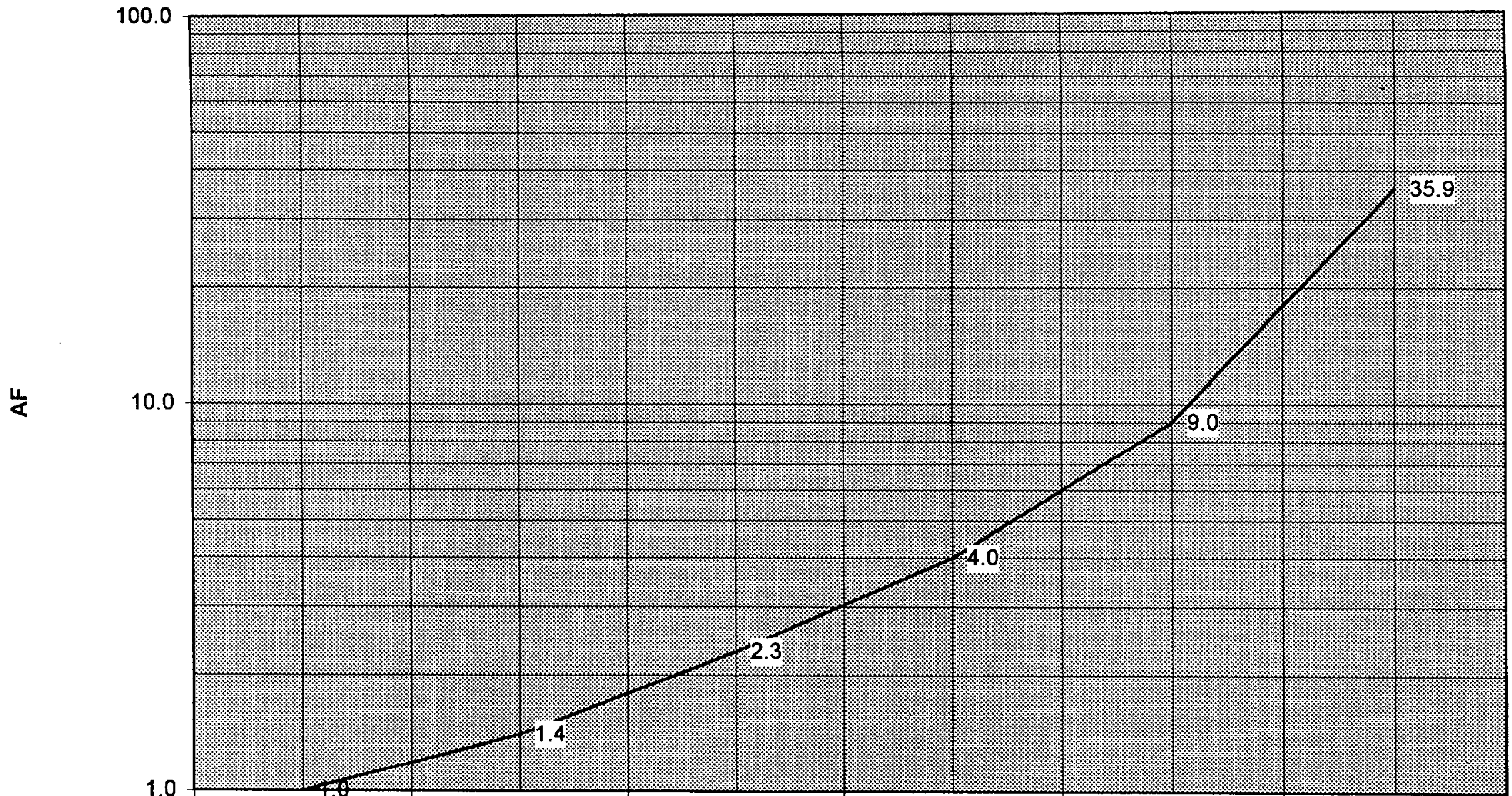
Eu155 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Eu155 AF	1.0	1.2	1.6	2.4	4.2	13.3

Area Size

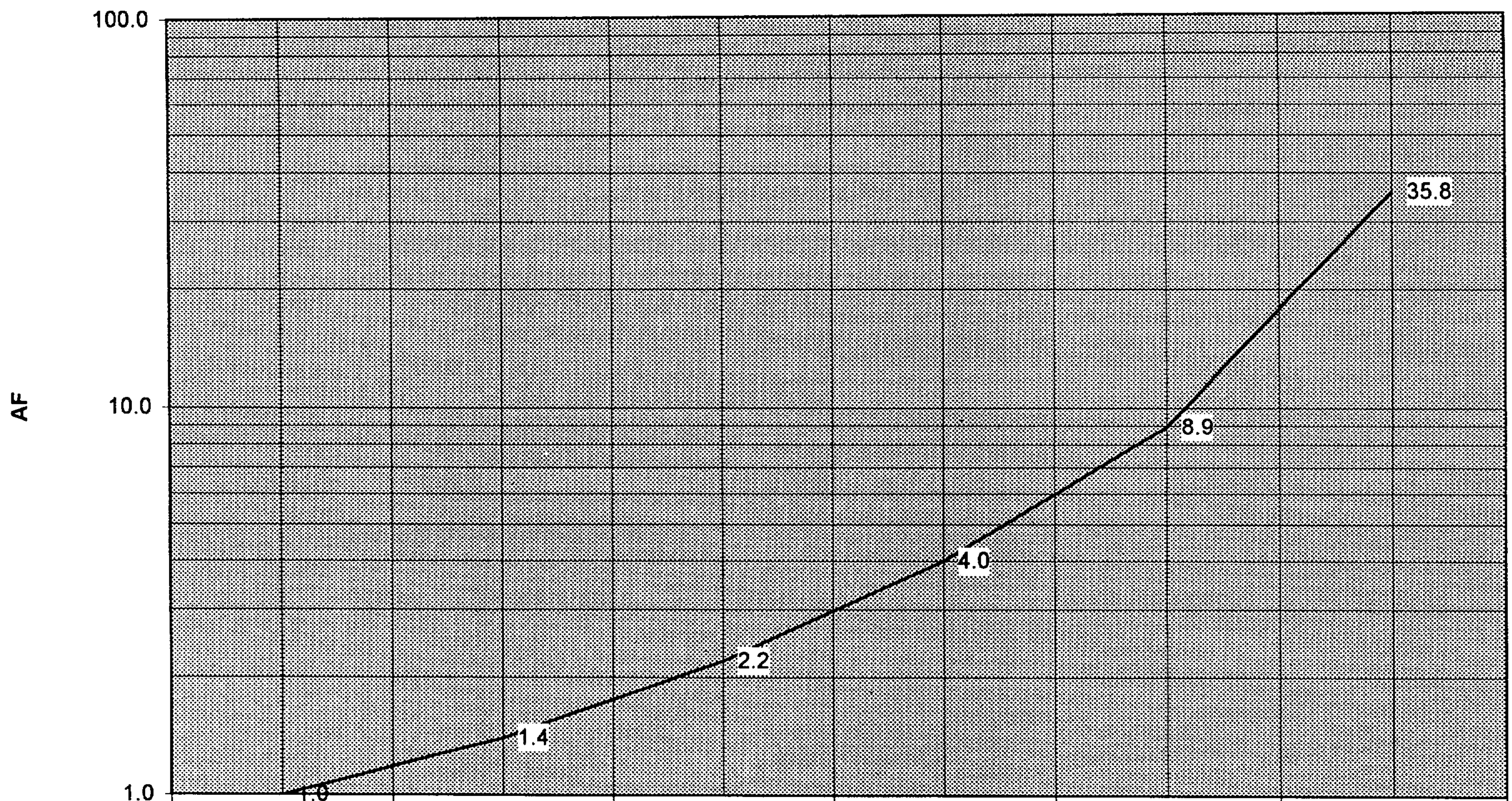
Fe55 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Fe55 AF	1.0	1.4	2.3	4.0	9.0	35.9

Area Size

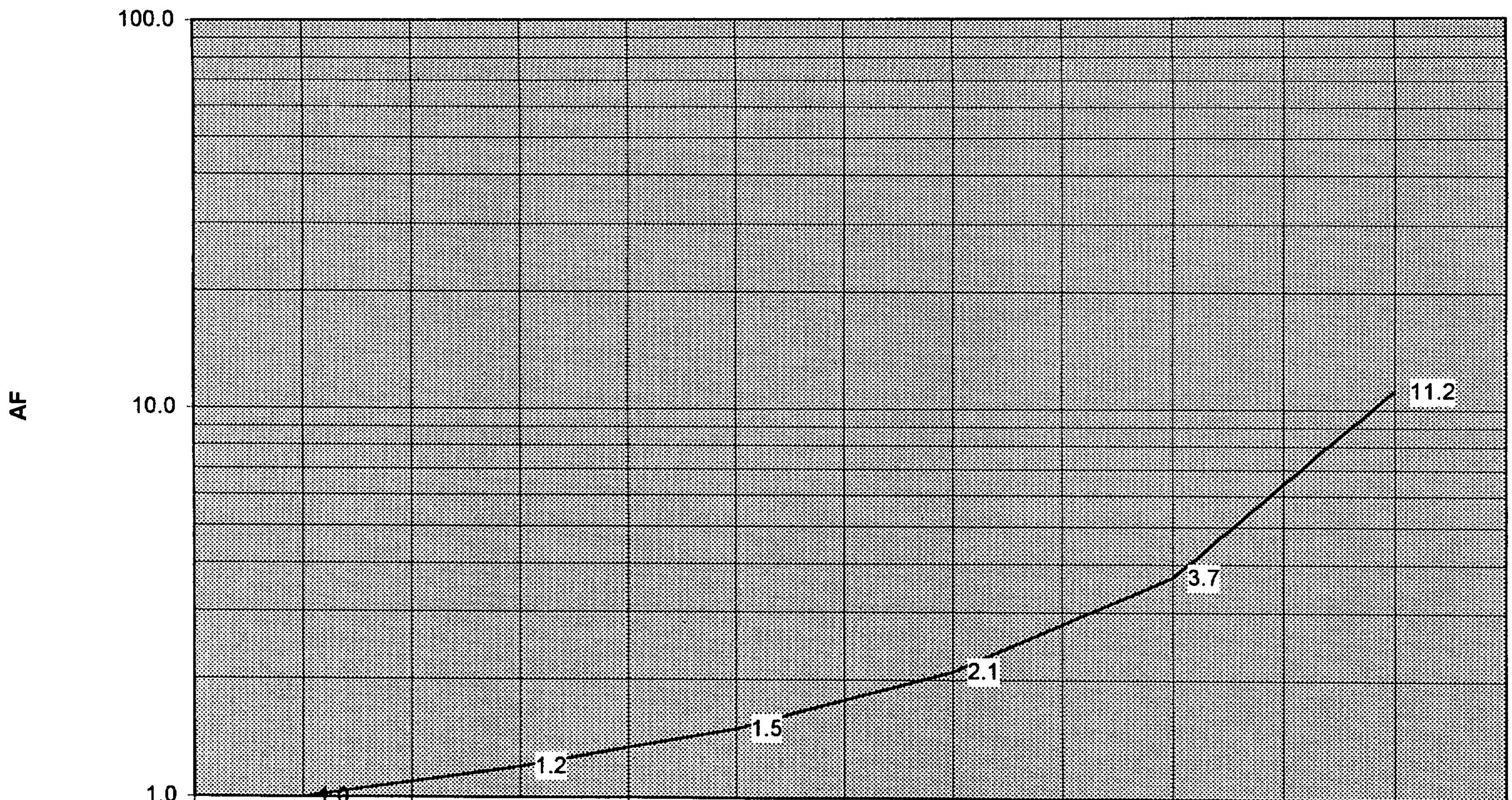
H3 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— H3 AF	1.0	1.4	2.2	4.0	8.9	35.8

Area Size

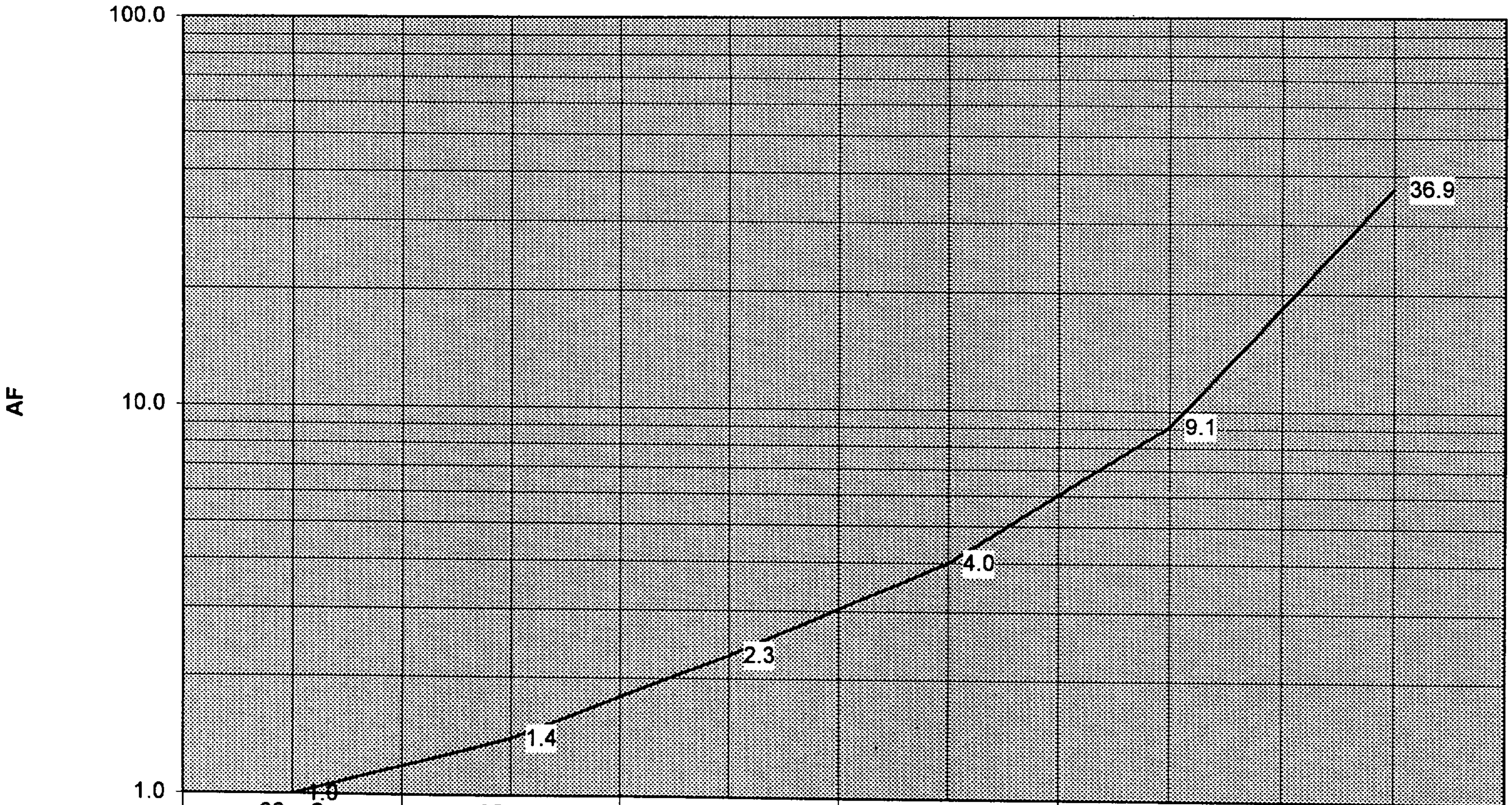
Nb94 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Nb94 AF	1.0	1.2	1.5	2.1	3.7	11.2

Area Size

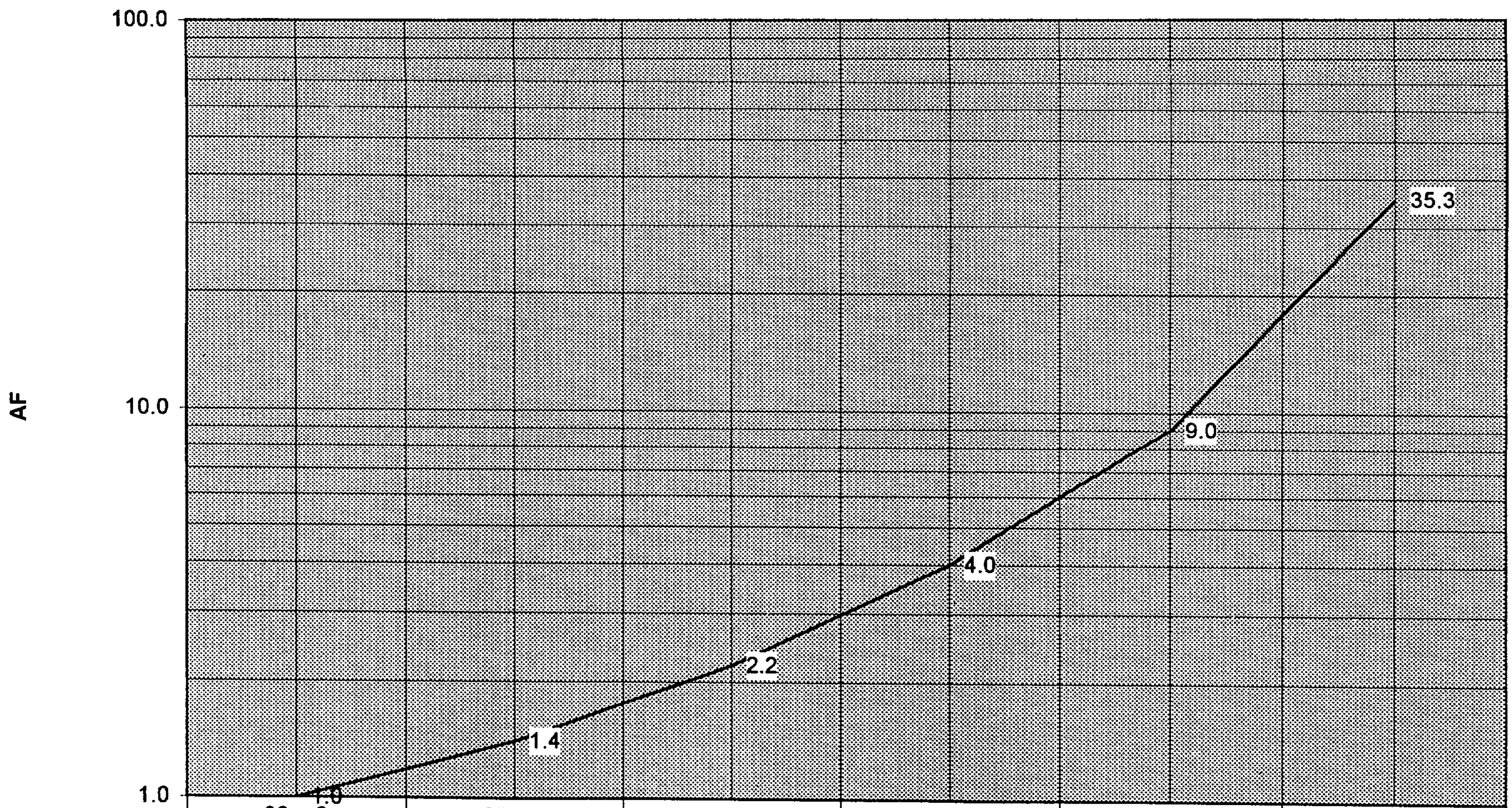
Ni59 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Ni59 AF	1.0	1.4	2.3	4.0	9.1	36.9

Area Size

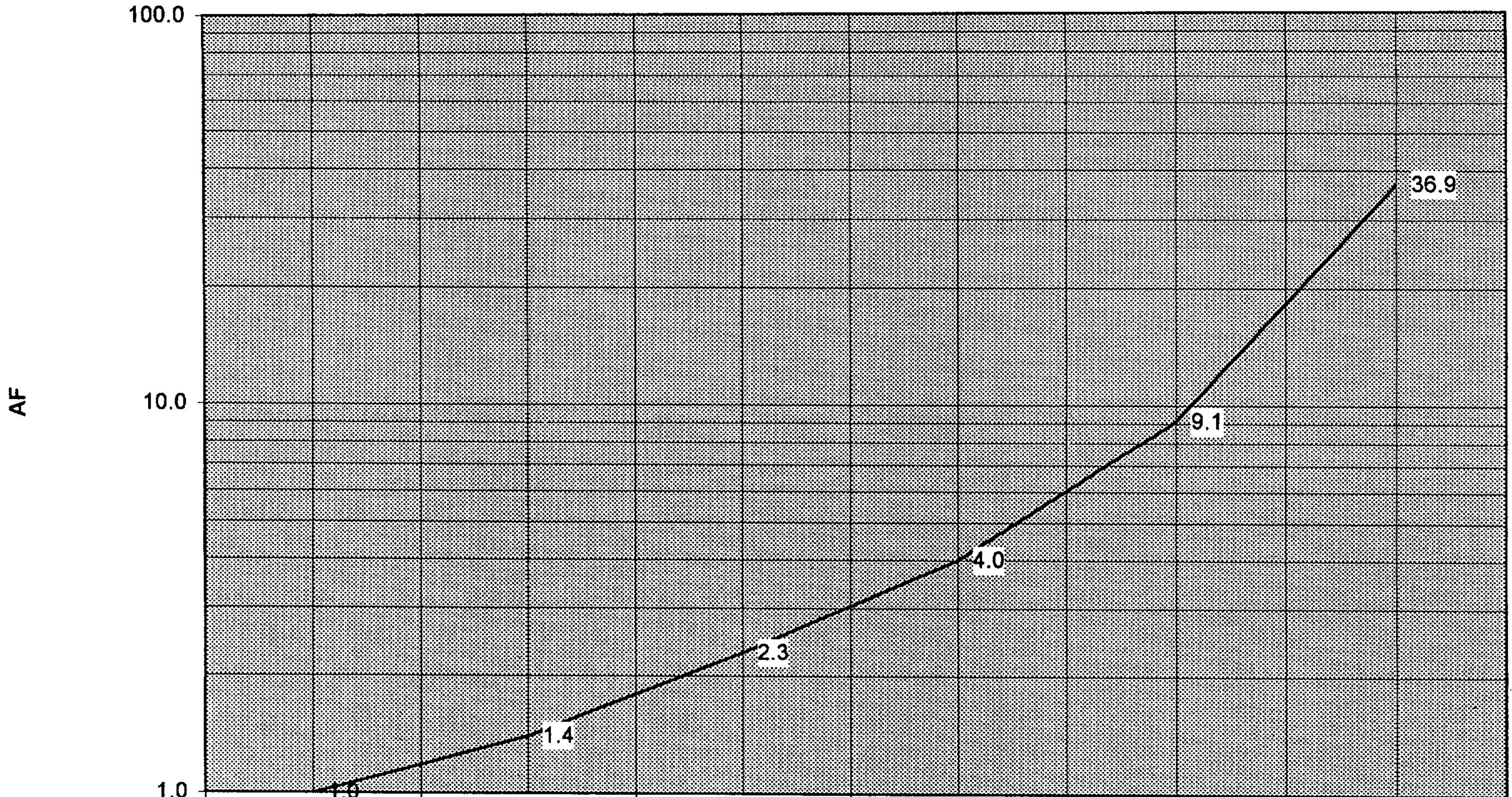
Ni63 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Ni63 AF	1.0	1.4	2.2	4.0	9.0	35.3

Area Size

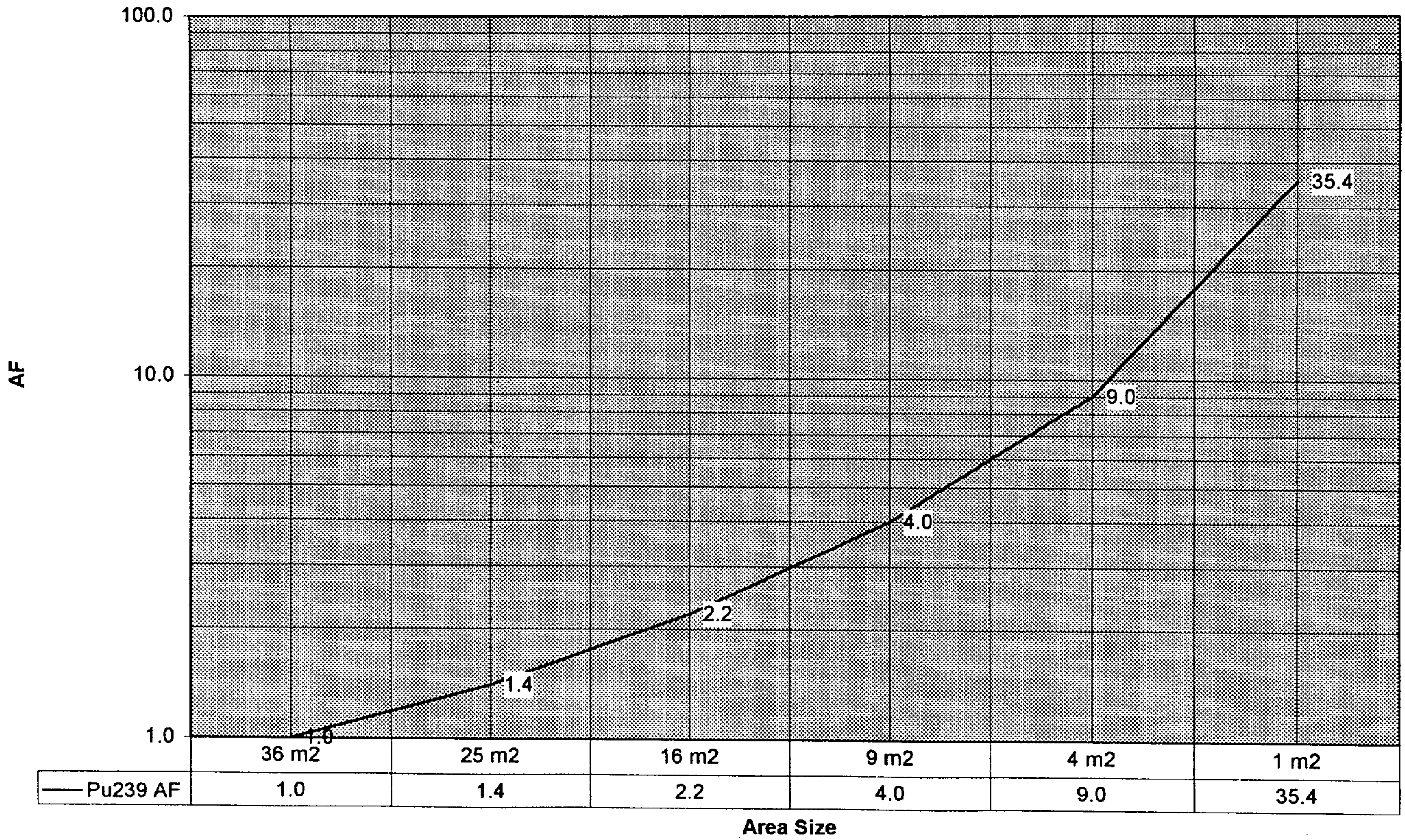
Pu238 Area Factors



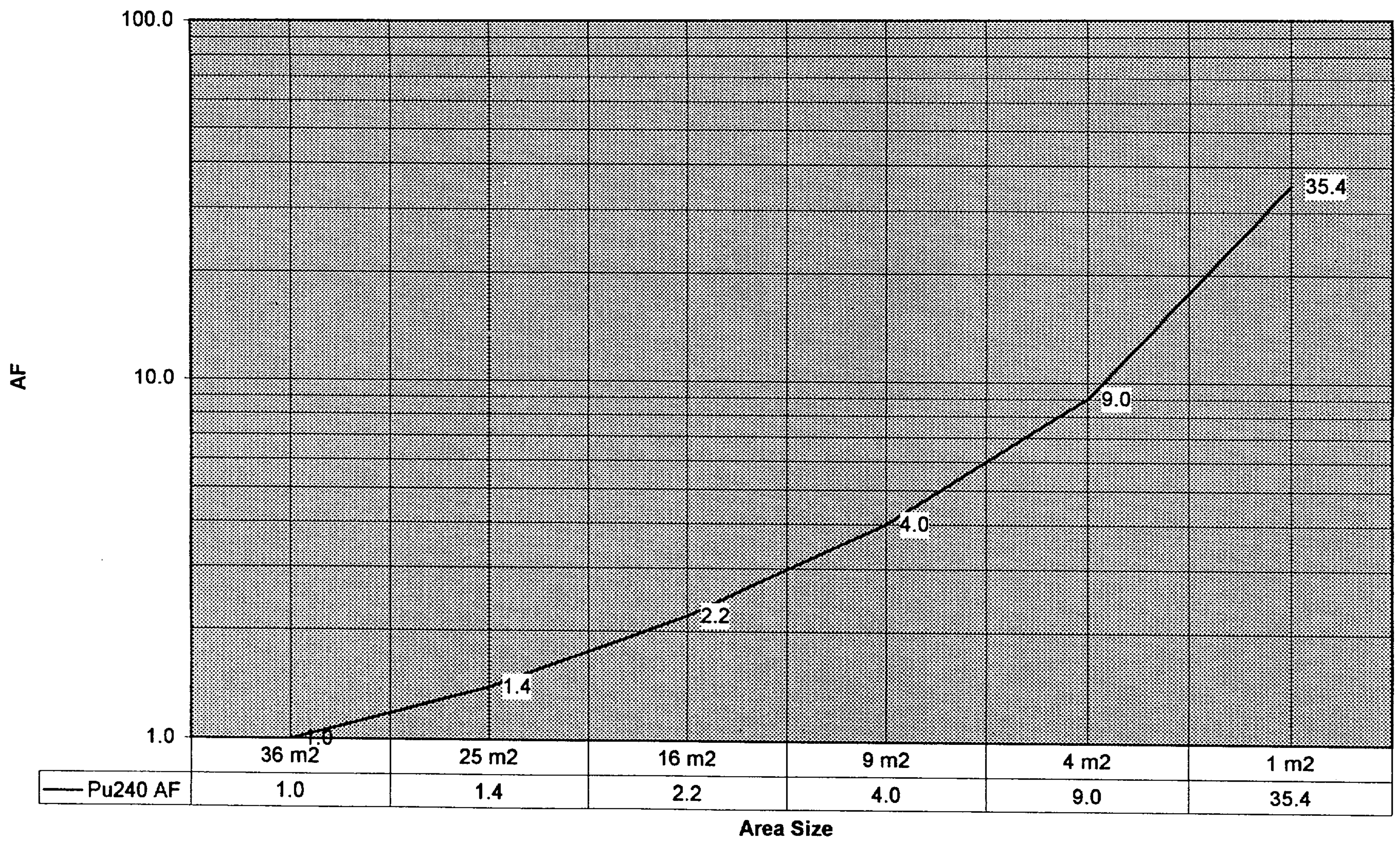
	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Pu238 AF	1.0	1.4	2.3	4.0	9.1	36.9

Area Size

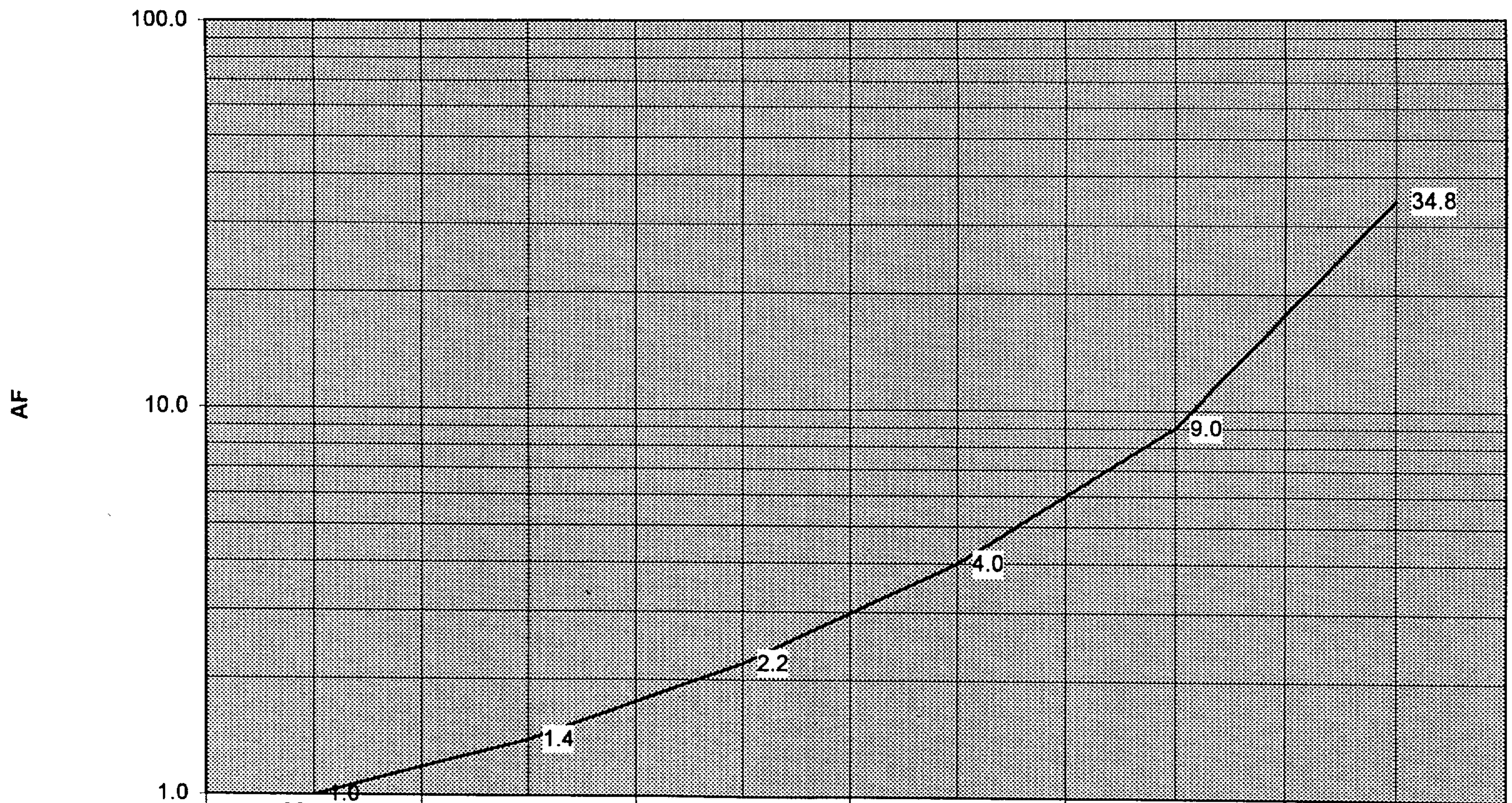
Pu239 Area Factors



Pu240 Area Factors



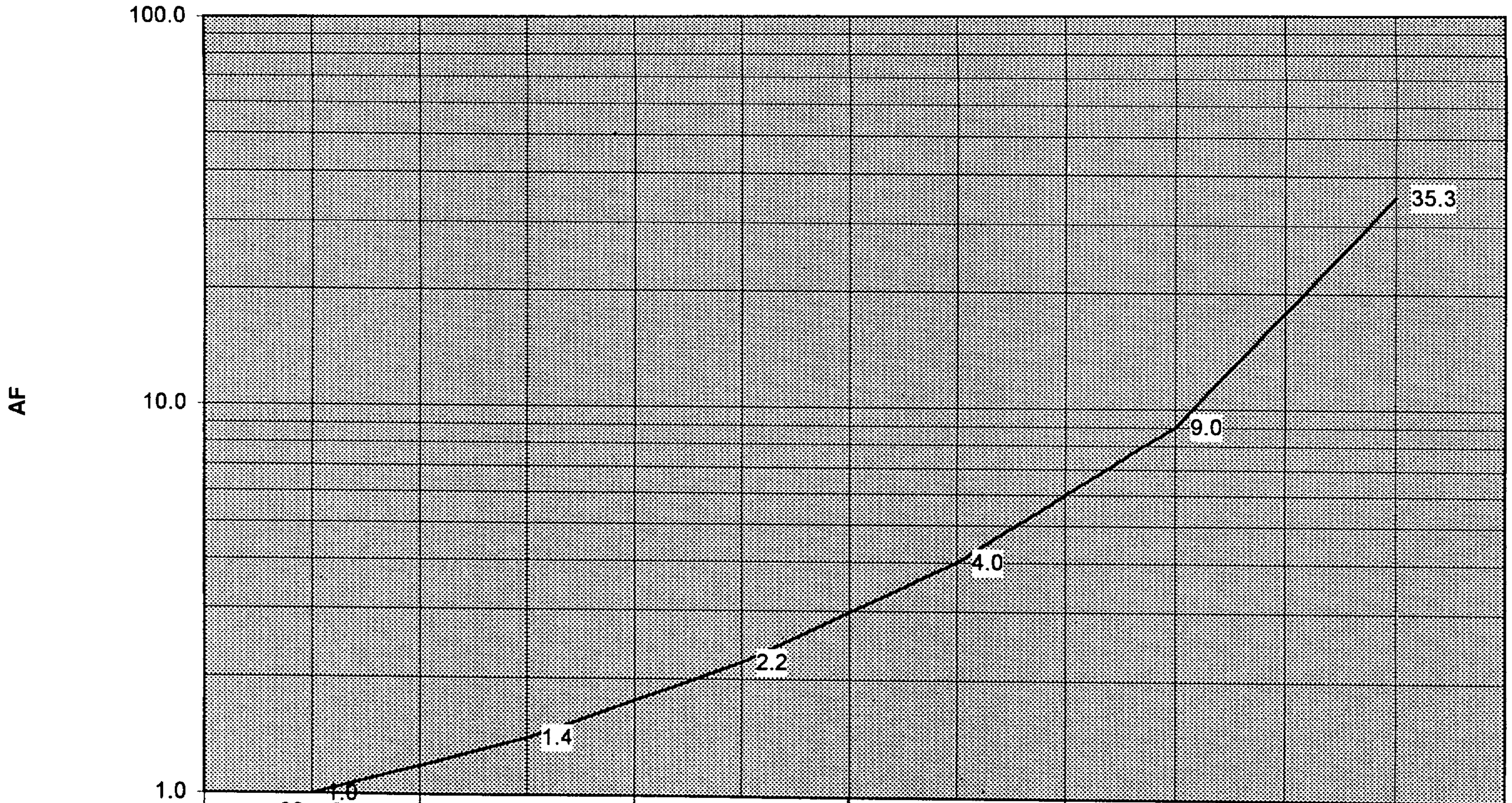
Pu241 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Pu241 AF	1.0	1.4	2.2	4.0	9.0	34.8

Area Size

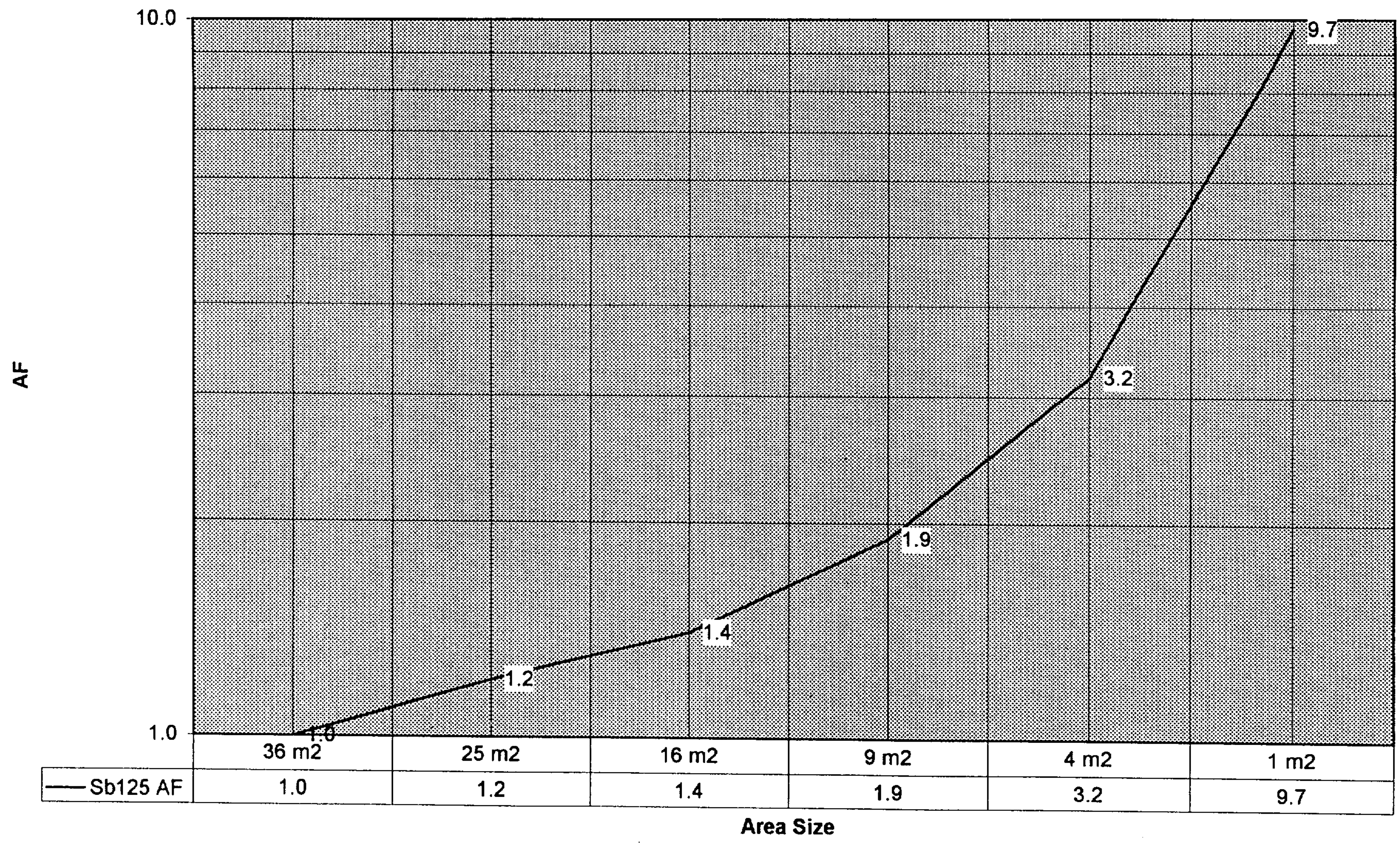
Pu242 Area Factors



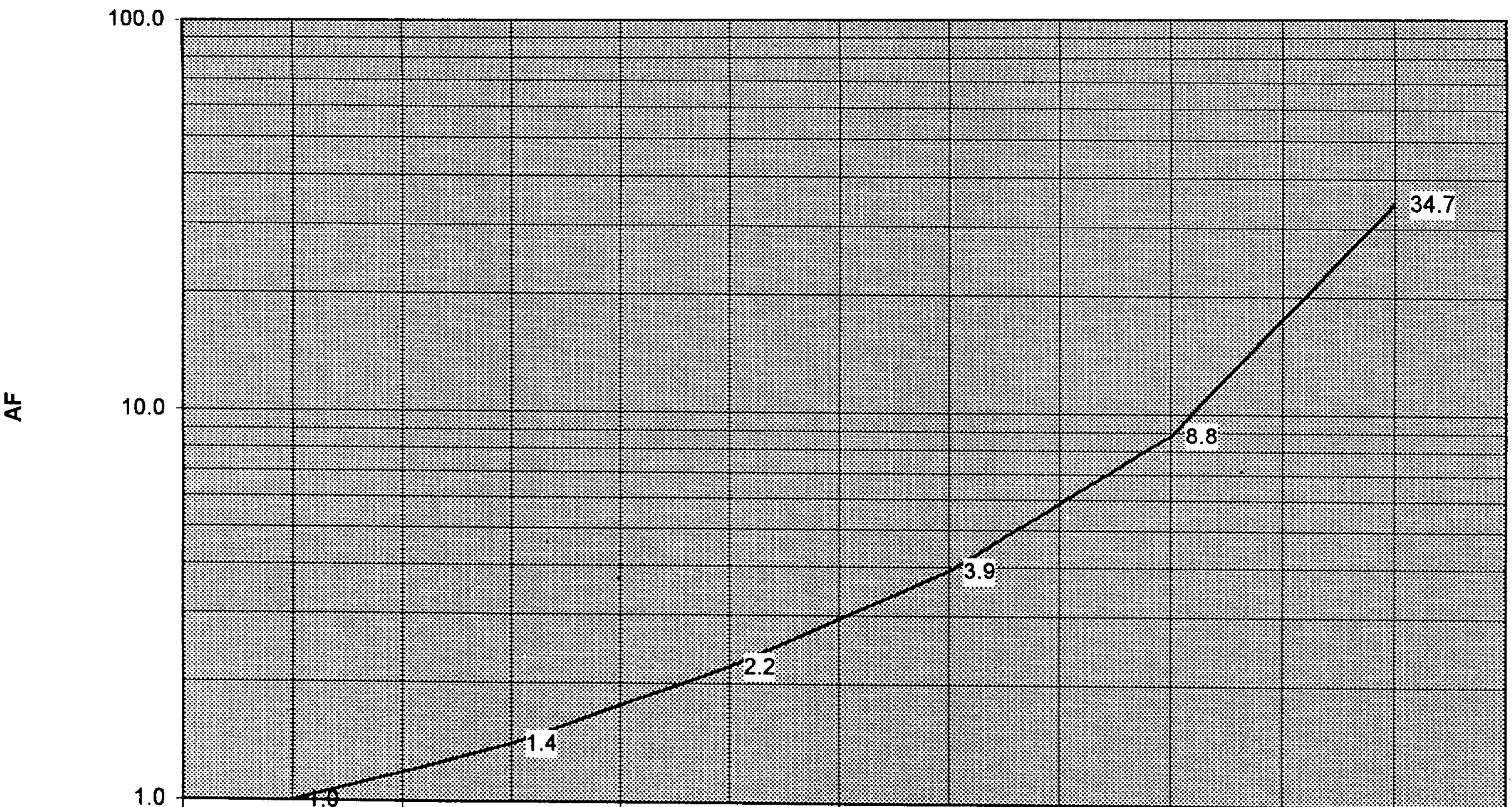
	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
Pu242 AF	1.0	1.4	2.2	4.0	9.0	35.3

Area Size

Sb125 Area Factors



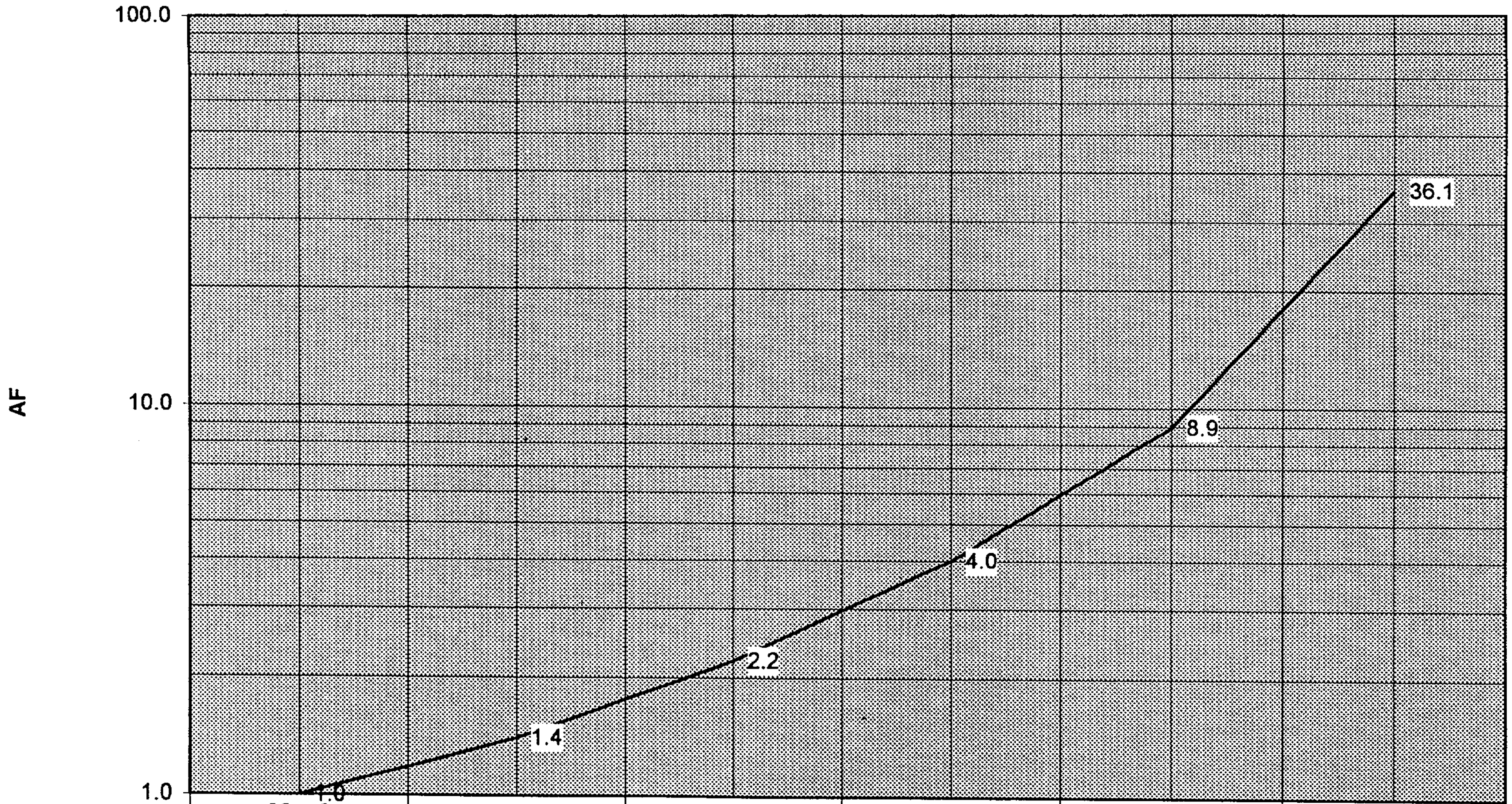
Sr90 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Sr90 AF	1.0	1.4	2.2	3.9	8.8	34.7

Area Size

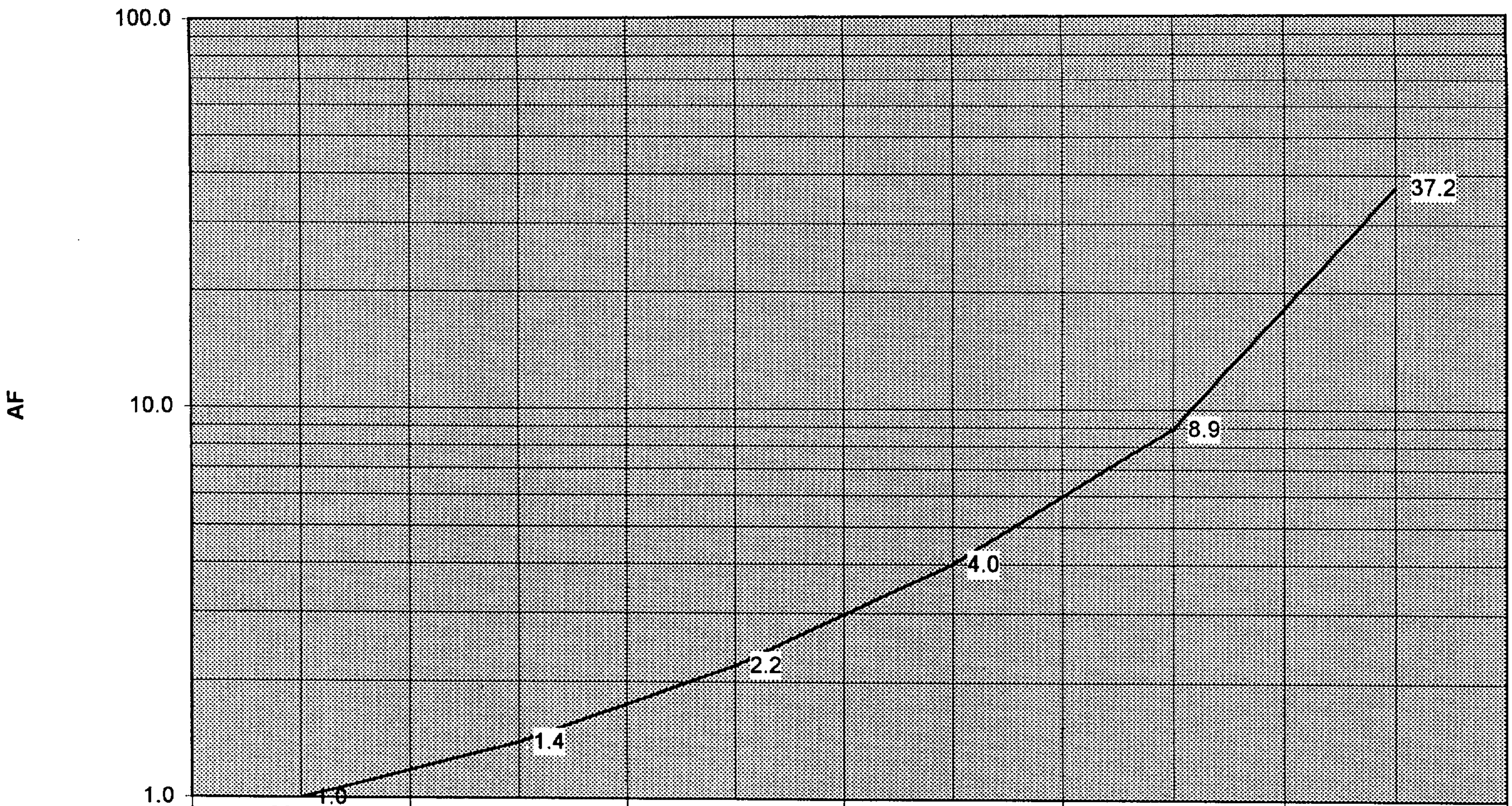
Tc99 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
—— Tc99 AF	1.0	1.4	2.2	4.0	8.9	36.1

Area Size

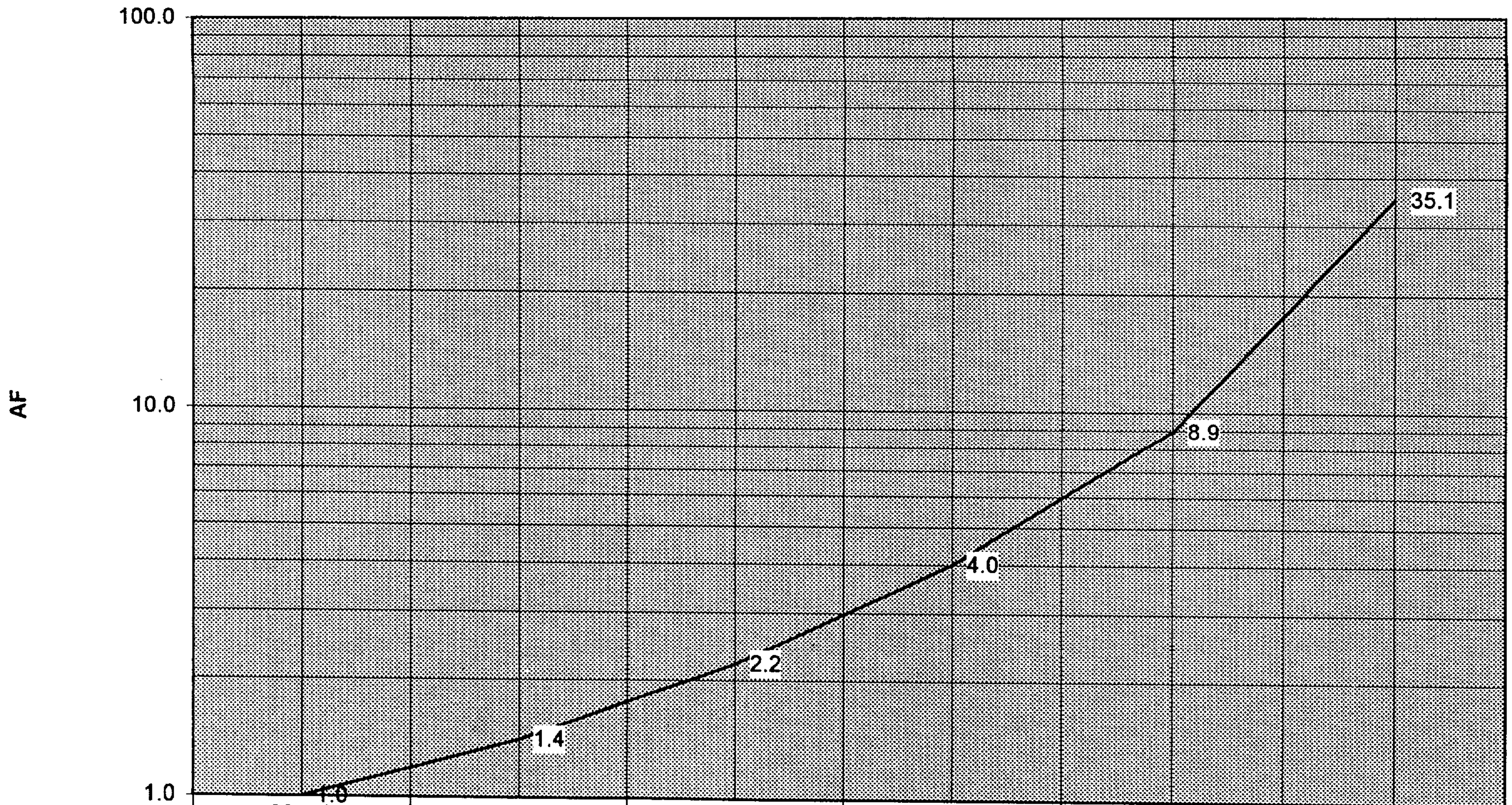
U234 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
U234 AF	1.0	1.4	2.2	4.0	8.9	37.2

Area Size

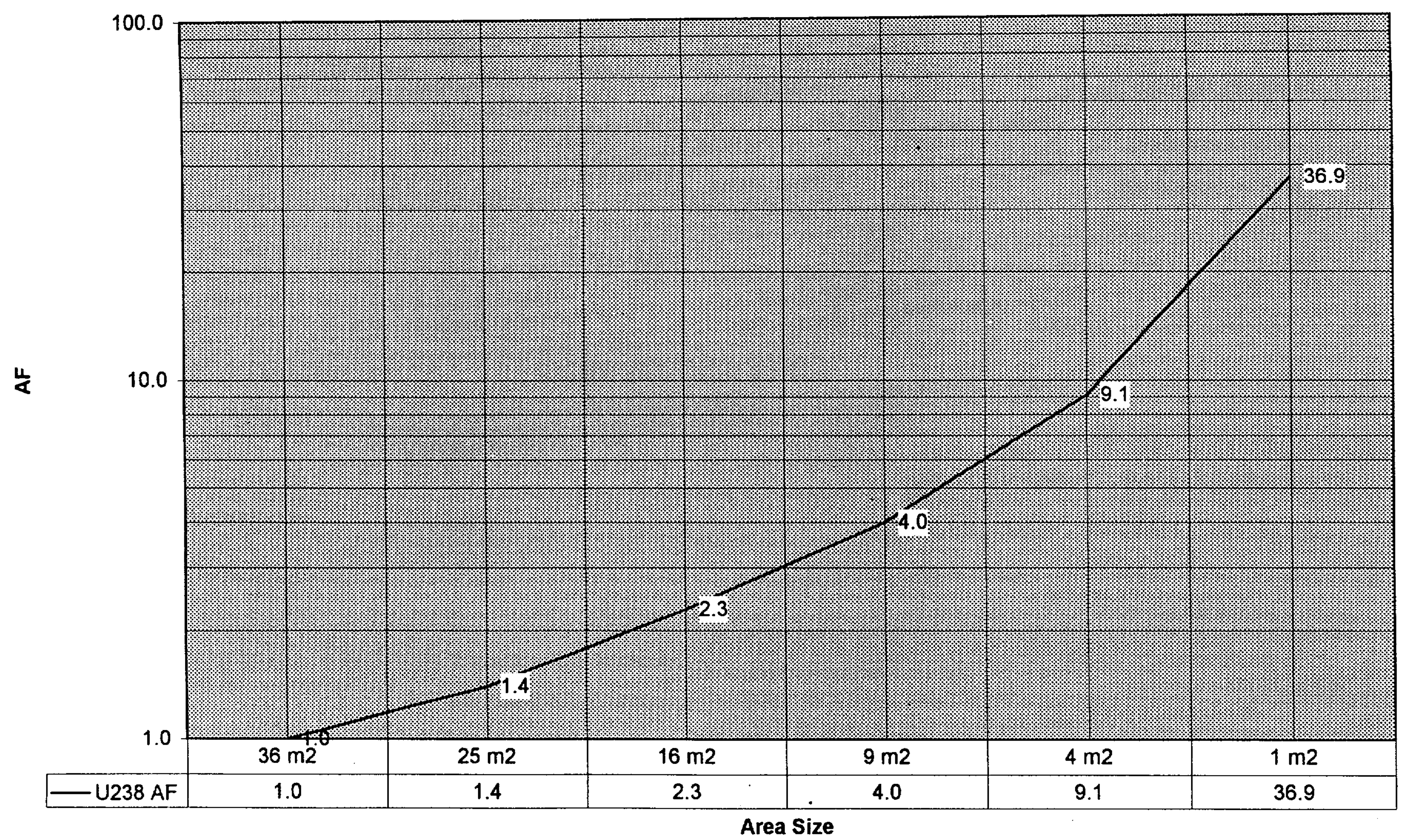
U235 Area Factors



	36 m2	25 m2	16 m2	9 m2	4 m2	1 m2
U235 AF	1.0	1.4	2.2	4.0	8.9	35.1

Area Size

U238 Area Factors



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K_d STUDY OF SITE SOILS AND CONSTRUCTION DEBRIS FROM THE SNEC DECOMMISSIONING PROJECT*

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for

Three Mile Island
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INTRODUCTION

Distribution coefficients (K_d) values are used in the RESRAD code to predict the behavior of radionuclides in soil. This behavior determines the movement of these nuclides from the soil in contact with groundwater. Depending on how each of these radioactive elements migrate, RESRAD will calculate the rate of movement from an individual site. These data are necessary in regulatory matters such as monitoring and surveillance issues. GPU Nuclear has contracted with Argonne to provide K_d measurements for their Saxton Nuclear Experimental Corporation Facility (SNEC). A list of radionuclides of concern (Table 1) was provided along with various soils and groundwater. In nearly all cases, Argonne provided experimentally the data for the list using either radioactive or stable elements (and stand-ins) to establish the values. The distribution for certain nuclides (^{3}H and ^{14}C) were estimated because of the uncertainty in the chemical form that these radionuclides would exhibit in the particular environmental condition. In the latter case, the K_d values (e.g. tritium oxide) are generally very low anyway.

Table 1. Requested Radionuclides

^{241}Am	$^{59,63}Ni$
$^{242,243,244}Cm$	$^{238-242}Pu$
^{60}Co	^{125}Sb
$^{134,137}Cs$	^{90}Sr
$^{152,154,155}Eu$	^{99}Tc
^{55}Fe	$^{234,235,238}U$
^{3}H	^{14}C
^{94}Nb	

EXPERIMENTAL

Samples for measurement of distribution coefficient were prepared from materials provided by GPU. Aliquots of the solids were air dried (Table 2) to obtain dry weight equivalents. Weighed, dried solids were given a preliminary examination by gamma counting using a high purity germanium detector (123% efficiency). Close agreement with the GPU "GAMMA SCAN" results were found except for sample #2. In the aliquot of the material examined by us, the Cs-137 and Co-60 contents were found to be 60 and 0.5 pCi/gram respectively (Table 5). We calibrated the germanium crystal using similar geometry and a NIST reference sediment (SRM 00389).

Table 2. Soil Data

Sample	As Received	Dry Wt.	Dry/Wet	For 100 gram Dry-Basis
S-1	58 grams	45	0.78	128
S-2	13.5	4.7	0.35	289*
S-3	22	18.5	0.84	119
S-4	57	47.3	0.83	121
S-6	26.5	22.9	0.86	116

NOTE: All other materials were nearly dry as received.

* Sample #2 was so highly hydrated that the sample for K_d measurement consisted of 133 grams dry-basis, 240 grams (ml) water associated (not recoverable by centrifugation) plus 100 ml site water added.

Site solids of 100 grams were combined with 100 ml of site water; both phases were matched according to location of recovery indicated by GPU labels. Before mixing the phases, each water portion was treated with an aliquot from a stock solution containing a variety of stable and radio tracers. A list of the elements and concentrations used are given in Table 4. A total of nine samples (two phases each) were treated with all selected radionuclides and stable elements. The ninth sample was a control, being an acid solution.

Table 3. Soil Identification and Analysis

Sample	Location	Date	Time	Weight (g)	Gamma Scan Results *	Water Source	Initial pH
1	River Sediment	6/21/01	15:45	1362	< 0.06 pCi/g	River Water	8
2	SSGS Debris	2/20/01	13:30	4089	190 (0.65-^{60}Co)	SSGS Tunnel End	7
3	Ash/Cinder Material	6/21/01	17:15	1664	< 0.08	GEO-1	6
4	CV Backfill Material	6/21/01	15:15	2024	0.2	GEO-5	6
5	CV Area Fill Soil	6/21/01	14:00	1810	< 0.09	GEO-4	6
6	CV Area Clay Material	6/21/01	14:30	2289	< 0.1	GEO-4	7
7	Weathered Bedrock/Clay	6/21/01	15:50	1878	< 0.09	GEO-5	6
8	Unweathered Bedrock	6/21/01	13:00	2882	Not Required	MW-4	10+

Data sheet from GPU enclosed with initial sample shipment.
*Data are for ^{137}Cs unless otherwise noted.

Table 4. Amounts of Isotopes or Elements Added

Nuclide	Initial Concentration Gammas per minute or Mass per 100 ml
Fe 59	90,000
Cs 137	92,000
Pu 239	1.55 μg
Am 241	-1030
U 235	5.17 μg
Tc 99	5.17 μg
Cd 109	970
Zn 65	2420
Co 60	1310
Ce 139	690
Hg 203	890
Sn 113	1030
Mn 54	-1400
Y 88	2050

NOTE: Include 5.17 μg each of a stable element mixture including Lead, Cadmium, Cobalt, Chromium, Copper, Strontium, Tin, Thallium, Zinc, and Zirconium

The contact period was for 20 days (September 26 - October 16, 2001). A brief mixing was done at the initial date and on five occasions during the contact, (September 28, October 1, 5, 8, 12, and 15). On October 16, all samples were first centrifuged to separate phases. Each recovered aqueous phase was run through a 0.45 μ membrane filter before examination for tracer recovery. The pH of the recovered aqueous phases was close to neutral (6.5 by narrow range paper). The solutions were analyzed using Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) or by gamma spectrometry previously mentioned.

RESULTS AND DISCUSSION

From these data, the K_d values were calculated. This value is arrived at by simply dividing the analyte of interest remaining in solution into the amount of analyte in the soil. If there were small amounts of a particular element present in the soil relative to the amount of spike, the K_d value was determined by the initial and final concentration of the element/radionuclide in the groundwater. This relationship was affected by the presence of that element/radionuclide in the initial soil that is significant relative to the spike. To understand better the soil chemistry, an analysis of the soil was deemed necessary. For example, for Pb K_d measurements, we added 5μg/sample. The initial soil contained from 3 to 1085 μg/g Pb or 300 to >100,000 μg Pb/sample (100g). A one gram aliquot of each soil sample was leached with a strong mineral acid (2M $HN0_3$) to determine the elements of interest. Results are shown in Table 6. Where appropriate, these data were used to calculate the K_d using both the initial concentration of the soil and remaining amount in liquid after soil/groundwater contact. NOTE: The soil analysis was important. Without these data, the K_d values would have been biased low.

Table 7 lists the final K_d values along with footnotes detailing estimated values and substituted or stand-in elements. The measured values in the first approximation, appear to be reasonable based on experience with similar type soils.

Table 5. Comparison of Ambient Soil Measurements

Sample	Cs-137 GPU	Cs-137 ANL
S-1	< 0.06 pCi/gram	0.062 ± 0.005 pCi/g
S-2*	[see Table 4]	60 ± 0.2
S-3	< 0.08	0.138 ± 0.015
S-4	0.2	0.347 ± -0.021
S-5	< 0.09	0.083 ± 0.008
S-6	< 0.1	0.095 ± 0.007
S-7	< 0.09	< 0.003
S-8	--	< 0.003

*ANL measurement, Co-60 = 0.5 ± 0.1
NOTE: Calibration at ANL with NIST SRM 00389

Table 6. Metals in Soil* (mg/Kg)

	S1	S2	S3	S4	S5	S6	S7	GR. S8
Cr	14.8	170	5.0	19	11	14	13	9.4
Mn	350	590	13.4	360	370	575	140	620
Co	17	22	1.8	9.6	12	14	11	12
Ni	32	98	4.0	13	16	18	25	23
Cu	13	370	15	19	8.8	25	32	25
Zn	104	1800	9.3	65	61	50	58	50
Sr	14	6.30	18	21	14	20	15	8.3
Zr	2.2	4.8	3.0	2.1	3.6	2.0	2.2	3.4
Cd	0.27	7.4	<0.01	<0.01	0.06	<0.01	<0.01	0.13
Sn	5.4	25	0.70	1.0	0.37	0.43	0.32	0.44
Sb	0.41	7.6	0.58	0.31	0.23	0.23	0.25	0.25
Ba	86	158	69	78	62	126	76	70
Tl	0.09	0.80	0.54	0.13	0.15	0.16	0.06	0.05
Pb	19	1085	29	36	14	26	7.0	2.6
U	0.47	1.2	0.32	1.0	0.50	1.2	0.76	0.52

*Concentration values by acid leaching.

Table 7. K_d Values (L/Kg)

	S1	S2	S3	S4	S5	S6	S7	[6]GR. S8
Tl	264	644	67	483	290	223	242	126
Tc-99	8.1	54	54	8.6	1.4	1.6	1.3	1.3
U-235	37	16	> 5200	17	34	106	> 5200	226
Pu-239	> 600	> 160	> 600	> 400	> 400	> 400	> 600	> 400
Cs-137	2340	2433	2131	> 14149	13618	2864	> 9746	> 28341
Sr	60	25	475	28	11	24	114	60
Sb	1100	153	5200	2070	1100	1800	>5000	1900
Pb	46,000	1.6E5	58,000	81,000	31,000	98,000	9,700	26,000
[1]C-14	~1	~1	~1	~1	~1	~1	~1	~1
[2]H-3	~1	~1	~1	~1	~1	~1	~1	~1
[3]Am-241	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Co-60	>1000	>1000	200	>1000	>1000	>1000	>1000	>1000
Mn-54	>1000	>1000	51	>1000	>1000	>1000	>1000	>1000
Zn	>1000	>5000	>300	>1000	>1000	>1000	>1000	>1000
Y-88	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000
[4]Ce-139	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Fe-59	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000
Hg-203	>100	>100	>100	>100	>100	>100	>100	>100
Sn-113	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Cd	>1300	8300	>200	>200	>200	>200	20	250
Ni	>10,000	>10,000	>4,000	>10,000	>10,000	>10,000	1300	1500
Cu	3300	>10,000	5600	5600	3000	>10,000	5700	>10,000
Cr	28,000	19,000	7500	>50,000	950	7,000	>36,000	1800
[5]Zr	>600	80	>500	>500	>500	>500	>500	>500

[1]The K_d value of 1 is an estimate for C-14 and assumes C-14 is in carbonate form.
[2]The K_d value of 1 is an estimate for H-3 and assumes H-3 is oxide or water.
[3]Am-241 values same for other trivalent actinides as Cm-242.
[4]Ce-139 is a stand-in for all rare earths as Eu-154. Y-88 is also a rare earth like element.
[5]Zr is a stand-in for Nb-94. Chemical similarity of these elements provides the basis for the substitution.
[6]GR.S8 was pulverized or ground.

GPU NUCLEAR	CALCULATION COVER SHEET	
Subject: SNEC Radionuclide List	**Calculation No.** E900-01-030	**Revision Number** 1

All revised areas denoted by change bars in right margin. Change bars denote only Revision 1 changes.

1. Section 1 – Reworded third sentence.
2. Section 2 – Summary of Results: Revised the Radionuclide List Table. Eliminated the inside/outside CV delineation and made the table a general radionuclide list.
3. Section 3 – Renumbered references. Added reference 3.11.
4. Section 4c&e – Added NCRP 45 information on background uranium in section 4c. Revised section 4e to eliminate the use of only 5 radionuclides outside the CV.
5. Section 5, Conclusions: Revised to use the list of 11 radionuclides inside the CV and select applicable radionuclides outside CV based on characterization data.
6. Section 6 – Revised title from Attachments to Appendices. Added Appendix numbers to Table 1-5.
7. Table 2 – Removed columns related to DCGLs.
8. Table 4 – Fixed footnote numbering and added new footnotes.
9. Table 5 – Re-titled the External table to Effective Dose Equivalent.

	Signature	Date
Originator	Pat Donnachie / [signature]	4/30/02
Reviewer	Barry Brosey / [signature]	4/30/02
Additional Reviewer	N/A	
Additional Reviewer	N/A	
Additional Reviewer	N/A	
Management Approval	A.F. Paynter / [signature]	02 May 02

RESRAD INPUT VALUES

Menu	Class	PARAMETERS	Basic RESRAD Input	SNEC Range of Values Min.	SNEC Range of Values Max.	Assigned Distribution	Default Distribution
C14	P	Thickness of Soil Evasion Layer of C-14 in Soil (m)	0.3	0.2	0.6	Triangular	
D-5	P	Bioaccumulation Factors, Fresh Water	Default Values	Varies	Varies	Lognormal	
D-34	P	Food Transfer Factors	Default Values	Varies	Varies	Lognormal	
N/A	P	Contaminated Zone Effective Porosity	Not Used	0.28	0.54	N/A	
RO11	P	Area of Contaminated Zone (m^2)	10000	N/A	N/A	N/A	
RO11	NRC	Basic Radiation Dose Limit (mrem/y) (NRC)	25	N/A	N/A	N/A	
RO11	P	Length Parallel to Aquifer Flow (m)	112.8	N/A	N/A	N/A	
RO11	P	Thickness of Contaminated Zone 1 (m)	1	N/A	N/A	N/A	
RO11	P	Time Since Placement of Materials (yr)	0	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	1	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	3	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	10	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	30	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	150	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	350	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	1000	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	10000	N/A	N/A	N/A	
RO13	P	Average Annual Wind Speed (m/sec)	4.07	3.13	4.83	Uniform	Bounded Longormal-N (1.4 - 13)
RO13	P	Contaiminated Zone Field Capacity	0.136	0.079	0.192	Uniform	None Assigned
RO13	P	Contaminated Zone b Parameter	5.6	4.05	7.12	Uniform	Bounded Longormal-N (0.5 - 30)
RO13	P, B	Contaminated Zone Erosion Rate (m/yr)	0.000345	0.00009	0.0006	Loguniform	Continuous Logarithmic (5E-08 - 0.2)
RO13	P	Contaminated Zone Hydraulic Conductivity (m/yr)	32.3	0.362	25400	Loguniform	Bounded Longormal-N (0.004 - 9250)
RO13	P	Contaminated Zone Total Porosity	0.46	0.35	0.56	Uniform	Truncated Normal, (0.157 - 0.693)
RO13	P	Cover Depth (m)	0	N/A	N/A	N/A	
RO13	P, B	Cover Depth Erosion Rate (m/yr)	Not Used	N/A	N/A	N/A	
RO13	P	Density of Contaminated Zone (g/cc)	1.6	1.28	1.92	Uniform	Truncated Normal (0.809 - 2.23)
RO13	P	Density of Cover Material (g/cc)	Not Used	N/A	N/A	N/A	
RO13	P	Evapotranspiration Coefficient (m/yr)	0.59	0.5	0.67	Uniform	Uniform (0.5 - 0.75)
RO13	P	Humidity in Air (g/m^3)	8	2.58E+00	2.03E+01	Truncated Lognormal-N	
RO13	B	Irrigation (m/yr)	0.2	---	---	None Assigned	
RO13	B	Irrigation Mode (Overhead)	Overhead	N/A	N/A	N/A	
RO13	P	Precipitation (m/y)	0.936	0.688	1.327	Uniform	None Assigned
RO13	P	Runoff Coefficient	0.35	0.3	0.4	Uniform	Uniform (0.1 - 0.8)
RO13	P	Watershed Area for Nearby Stream or Pond (m^2)	5.00E+06	---	---	None Assigned	None Assigned
RO14	P	Density of Saturated Zone (g/cc)	1.6	1.28	1.92	Uniform	Truncated Normal (0.809 - 2.23)
RO14	P	Model: Non-dispersion (ND) or Mass-Balance (MB)	Non-Dispersion	N/A	N/A	N/A	
RO14	P	Saturated Zone b Parameter	Not Used	N/A	N/A	N/A	
RO14	P	Saturated Zone Effective Porosity	0.028	0.005	0.05	Loguniform	Truncated Normal (0.075 - 0.635)
RO14	P	Saturated Zone Hydraulic Conductivity (m/yr)	67.91	15.59	909.53	Uniform	Bounded Longormal-N (0.004 - 9250)
RO14	P	Saturated Zone Hydraulic Gradient	0.02	0.013	0.03	Uniform	Bounded Longormal-N (0.00007 - 0.5)
RO14	P	Saturated Zone Total Porosity	0.36	0.31	0.41	Uniform	Truncated Normal, (0.157 - 0.693)
RO14	P	Water Table Drop Rate (m/yr)	0	---	---	None Assigned	None Assigned
RO14	P	Well Pump Intake Depth (m)	30	10	50	Uniform	Triangular (6 -30)
RO14	B, P	Well Pumping Rate (m^3/yr)	286.2	207.3	365	Uniform	None Assigned
RO14	P	Saturated Zone Field Capacity	0.136	0.079	0.192	Uniform	None Assigned
RO15	P	Density of Unsaturated Zone 1 (g/cc)	1.6	1.28	1.92	Uniform	Truncated Normal (0.809 - 2.23)
RO15	P	Effective Porosity of Unsaturated Zone 1	0.41	0.28	0.54	Uniform	Truncated Normal (0.075 - 0.635)
RO15	P	Hydraulic Conductivity of Unsaturated Zone 1 (m/yr)	32.3	0.362	25400	Loguniform	Bounded Longormal-N (0.004 - 9250)
RO15	P	Number of Unsaturated Zone Strata	1	N/A	N/A	N/A	N/A
RO15	P	Thickness of Unsaturated Zone 1 (m)	0.25	0	0.5	Uniform	Bounded Longormal-N (0.18 - 320)

RO15	P	Total porosity of Unsaturated Zone 1	0.46	0.35	0.56	Uniform	Truncated Normal, (0.157 - 0.693)
RO15	P	Unsaturated Zone 1 b Parameter	5.6	4.05	7.12	Uniform	Bounded Longormal-N (0.5 - 30)
RO15	P	Unsaturated Zone Field Capacity	0.136	0.079	0.192	Uniform	None Assigned
RO17	P	External Gamma Shielding Factor	0.5512	4.400E-02	1	Bounded Lognormal-N	
RO17	P, B	Indoor Dust Filtration Factor	0.4	0.15	0.95	Uniform	
RO17	B	Indoor Time Fraction	0.66	0	1	Continuos Linear	
RO17	M, P	Inhalation Rate (m^3/yr)	8400	4380	13100	Triangular	
RO17	P, B	Mass Loading for Inhalation (g/m^3)	0.00000314	0	0.0001	Continuos Linear	
RO17	B	Fraction of Time Spent Outdoors	0.12	---	---	None Assigned	
RO18	B, P	Contaminated Fraction of Aquatic Food	1	0	1	Triangular	
RO18	B, P	Contaminated Fraction of Drinking Water	1	---	---	None Assigned	
RO18	B, P	Contaminated Fraction of Household Water	Not Used	N/A	N/A	N/A	
RO18	B, P	Contaminated Fraction of Irrigation Water	1	---	---	None Assigned	
RO18	B, P	Contaminated Fraction of Livestock Water	1	---	---	None Assigned	
RO18	B, P	Contaminated Fraction of Meat	1	---	---	None Assigned	
RO18	B, P	Contaminated Fraction of Milk	1	---	---	None Assigned	
RO18	B, P	Contaminated Fraction of Plant Food	1	---	---	None Assigned	
RO18	M, B	Drinking Water Intake (L/yr)	478.5	90.4	1860	Truncated Lognormal-N	
RO18	M, B	Fish Consumption (kg/yr)	20.6	---	---	None Assigned	
RO18	M, B	Fruit, Vegetable, and Grain Consumption (kg/yr)	111.8	135	318	Triangular	
RO18	M, B	Leafy Vegetable Consumption (kg/yr)	21.4	---	---	None Assigned	
RO18	M, B	Meat and Poultry Consumption (kg/yr)	67	---	---	None Assigned	
RO18	M, B	Milk Consumption	233	60	200	Triangular	
RO18	M, B	Other Seafood Consumption (kg/yr)	0.9	---	---	None Assigned	
RO18	M, B	Soil Ingestion Rate (g/yr)	18.3	0	36.5	Triangular	
RO19	M, B	Depth of Roots (m)	0.9	0.3	4	Uniform	
RO19	M, B	Depth of Soil Mixing Layer (m)	0.15	0	0.6	Triangular	
RO19B	M, B	Weathering Removal Constant of all Vegetation	20	5.1	84	Triangular	
RO19B	M, B	Wet Crop Yield for Fodder (kg/m^2)	1.1	---	---	None Assigned	
RO19B	M, B	Wet Crop Yield for Leafy (kg/m^2)	1.5	---	---	None Assigned	
RO19B	M, B	Wet Crop Yield for Non-Leafy (kg/m^2)	0.7	0.397	7.72	Truncated Lognormal-N	
RO19B	M, B	Wet Foliar Inception Fraction of Leafy Vegetables	0.25	0.06	0.95	Triangular	
STOR	B	Storage Times for Livestock Fodder	0	---	---	None Assigned	
RO19	M, B	Livestock Water Intake for Milk	60	---	---	None Assigned	

		Distribution Coefficient for Americium & Curium	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	1000	1000	5000		
R16	P	2. Unsaturated Zone (cm^3/g)	1000	1000	5000		
R16	P	3. Saturated Zone (cm^3/g)	1000	1000	5000		
		Distribution Coefficient for Carbon	**ANL Value**	**GPU Min.**	**GPU Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	~1	0	5	Uniform	
R16	P	2. Unsaturated Zone (cm^3/g)	~1	0	5	Uniform	
R16	P	3. Saturated Zone (cm^3/g)	~1	0	5	Uniform	
		Distribution Coefficient for Cesium	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	2131	2131	28341		
R16	P	2. Unsaturated Zone (cm^3/g)	2131	2131	28341		
R16	P	3. Saturated Zone (cm^3/g)	2131	2131	28341		
		Distribution Coefficient for Cobalt	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	200	200	1000		
R16	P	2. Unsaturated Zone (cm^3/g)	200	200	1000		
R16	P	3. Saturated Zone (cm^3/g)	200	200	1000		
		Distribution Coefficient for Europium	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	1000	1000	5000		
R16	P	2. Unsaturated Zone (cm^3/g)	1000	1000	5000		
R16	P	3. Saturated Zone (cm^3/g)	1000	1000	5000		
		Distribution Coefficient for Hydrogen	**ANL Value (GPU)**	**GPU Min.**	**GPU Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	~1 (0.25)	0	0.5	Uniform	
R16	P	2. Unsaturated Zone (cm^3/g)	~1 (0.25)	0	0.5	Uniform	
R16	P	3. Saturated Zone (cm^3/g)	~1 (0.25)	0	0.5	Uniform	
		Distribution Coefficient for Iron	**Value Used**	**GPU Min.**	**GPU Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	10000	10000	50000		
R16	P	2. Unsaturated Zone (cm^3/g)	10000	10000	50000		
R16	P	3. Saturated Zone (cm^3/g)	10000	10000	50000		
		Distribution Coefficient for Lead	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	9700	9700	160000		
R16	P	2. Unsaturated Zone (cm^3/g)	9700	9700	160000		
R16	P	3. Saturated Zone (cm^3/g)	9700	9700	160000		
		Distribution Coefficient for Nickel	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	1300	1300	10000		
R16	P	2. Unsaturated Zone (cm^3/g)	1300	1300	10000		
R16	P	3. Saturated Zone (cm^3/g)	1300	1300	10000		
		Distribution Coefficient for Plutonium	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	160	160	600		
R16	P	2. Unsaturated Zone (cm^3/g)	160	160	600		
R16	P	3. Saturated Zone (cm^3/g)	160	160	600		
		Distribution Coefficient for Strontium	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	11	11	475		
R16	P	2. Unsaturated Zone (cm^3/g)	11	11	475		
R16	P	3. Saturated Zone (cm^3/g)	11	11	475		
		Distribution Coefficient for Uranium	**Value Used**	**ANL Min.**	**ANL Max.**	**Distribution Type**	
R16	P	1. Contaminated Zone (cm^3/g)	16	16	5200		
R16	P	2. Unsaturated Zone (cm^3/g)	16	16	5200		
R16	P	3. Saturated Zone (cm^3/g)	16	16	5200		

NOTE: ANL Kd values may be "greater than" values. The ANL Min. value is the lowest reported value for this element and the ANL Max. value is the highest reported value.
NOTE: Items in RED type face are SNEC input values.
NOTE: Items with BLUE background are D & D default values, while items with a YELLOW background are RESRAD default values.

GPU NUCLEAR

Calculation Sheet

Subject	Calc. No.	Rev. No.	Sheet No.
SNEC Radionuclide List	E900-01-030	1	1 of 6

Originator	Date	Reviewed by	Date
Pat Donnachie [signature]	April 30, 2002	Barry Brosey [signature]	4/30/02

1. Purpose

The purpose of this calculation is to document the most representative list of radionuclides to be considered at SNEC and to provide verification why some radionuclides were selected and others were not. Chapter 5, Table 5-1 of the SNEC License Termination Plan (LTP), Revision 0, contains a list of 26 radionuclides that have derived concentration guidelines (DCGLs) calculated. These radionuclides were either identified as part of the site characterization process or based on current knowledge at the time. This data was selected from the SNEC Characterization Report (Reference 3.1). To date more analytical information has been collected in justifying a better representation of radionuclides found at SNEC. In addition, a formal process, based on regulatory guidance, has been implemented to select radionuclides applicable to the site.

Determining a representative list of radionuclides provides the following:

a. Increased efficiencies and clearer guidance for sampling and analysis.
b. Emphasis on radionuclides contributing significant doses to the public.
c. More efficient regulatory review.
d. Simplification of dose models.
e. Analytical cost reduction.

2. Summary of results

Guidance from NUREG/CR-3474 and NUREG/CR-0130 (References 3.6 & 3.7) was used to first develop a comprehensive list of radionuclides (Table 4) that could potentially be found in media at SNEC, during its operation and post shutdown periods. From this list various criteria was used to deselect radionuclides. Information on site-specific radionuclides was also determined using results of characterization surveys, waste stream analyses and historical site assessments that are appropriate for each medium. Once a list was developed a 4-step process was used to deselect radionuclides that are not applicable to SNEC.

Step 1 - SNEC has been shut down for almost 30 years. All radionuclides with half lives less than 3 years have been deselected since they have decayed 10 half lives.
Step 2 - Over 500 samples in various media have been analyzed as part of the characterization process. Radionuclide results below minimum detectable activity (MDA) levels were deselected.
Step 3 – Radionuclides in media that were < 1% of the total mix activity <u>and</u> < 10% of the dose limit were also deselected. Per Appendix E of NUREG-1727 (Reference 8) radionuclides contributing < 10% of the dose limit can be screened out.
Step 4 – Evaluate which media contain certain radionuclides.

As a result of the deselecting process and most recent characterization data, a table has been developed listing radionuclides present at the SNEC site. This table represents a comprehensive list of radionuclides potentially found in volumetric media and on surface areas.

SNEC Radionuclide List Table

H-3	Eu-152
C-14	Pu-238
Co-60	Pu-239
Ni-63	Pu-241
Sr-90	Am-241
Cs-137	

3. References:

3.1 SNEC Facility Site Characterization Report, May 1996

3.2 SNEC License Termination Plan, February 2000

3.3 SNEC Historical Site Assessment Report, March 2000

3.4 SNEC Soil Characterization Report, May 1995

3.5 File W:/Donnachie/Nuclide Laboratory Analysis Results.xls

3.6 NUREG/CR-3474, "Long-lived Activation Products in Reactor Materials", August 1984.

3.7 NUREG/CR-0130, "Technology, Safety, and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station", June 1978.

3.8 NUREG-1727, "NMSS Decommissioning Standard Review Plan", September 2000.

3.9 Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", September 1988.

3.10 Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil", September 1993.

3.11 NCRP Report No. 45, "Natural Background Radiation in the United States," pg 46, November 15, 1975.

4. Assumptions and Basic Data

The following criteria was used to determine a reasonable list of radionuclides that are significant at the SNEC site (Reference Table 3.4):

a. NUREG/CR- 0130 & 3474 guidance for selection of radionuclides in PWR station media. The following tables from these NUREGs were used to determine a comprehensive list of radionuclides from which a deselection process could be used, i.e. NUREG/CR-3474, Tables 1.1, 5.4 & 5.6 and NUREG/CR-0130, Volumes 1 & 2, Tables 7.3-5, 7.3-11, 7.3-14, C.1-3, C.1-5, E.2-1, E.2-2 & E.2-3. This list is consistent with the regulatory guidance for radionuclides of concern in bio-shield wall concrete, rebar, and surface contamination and site deposition from radioactive releases. A total of 71 radionuclides initially made the comprehensive list as a result of the NUREG tables review and, also, through the addition of some transuranic nuclides not contained in the NUREG tables. However, many radionuclides in the regulatory guidance are not applicable to SNEC based on short half-life, low relative abundance in media mix, or inconsequential dose contribution.

b. Deselect radionuclides that have decayed 10 half lives (i.e. radionuclides with half-life < 3 years). This method takes into account SNEC's 30 year shut down period. A total of 31 radionuclides with half-lives less than 3 years were deselected from the initial list leaving 40 radionuclides remaining.

c. Evaluate positively identified radionuclides (i.e. gamma emitters, hard to detect and transuranic nuclides) identified above MDA. Gamma scan results on over 540 samples were reviewed from the SNEC characterization electronic database. In addition, transuranic and hard to detect radionuclides were reviewed from technical reports and laboratory analysis data. Sample media consisted of smears, core bores, pipe scrapings, soil, sediment and water. Samples were obtained from CV system components & piping, structural concrete, surface & sub-surface soils, site wells, CV paint and SSGS related structures. A total of 21 radionuclides were deselected as being less than MDA leaving 19 radionuclides remaining. Of these 19, two radionuclides (Fe-55 & Cm-242) have half-lives less than 3 years but were detected slightly above MDA in a few samples. However, they are less than 1% of the mix activity and will be deselected.

   Per Reference 3.11 one gram of natural uranium contains 0.33 uCi of U-238, 0.015 uCi of U-235 and 0.3 uCi of U-234, subject to minor variations in U-234. U-234, U-235 and U-238 have been detected in samples. Results of these uranium nuclides are listed in Table 2. An evaluation was made to determine if these uraniums were plant produced or naturally occurring. Table 3 presents the estimated activities for each uranium as it is found in nature. Nuclide ratios (U234/U238, U238/U235 & U234/U235) were calculated with specified uncertainty ranges. From this information SNEC samples contain naturally occurring uranium.

The following technical reports and analytical data were reviewed:

SNEC Facility Characterization Report, May 1996:
Tables 4-1, 4-5, 4-6, 4-7, 4-8, 4-10, 4-13, 4-17, 4-20, 4-21, 4-25, 4-27, 4-28, 4-29, 4-30, 4-31, 4-53

SNEC License Termination Plan, February 2000 – Revision 0:
Tables 2-1, 2-2, 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, 2-9, 2-10, 2-12, 2-14, 2-15, 2-16, 2-17

SNEC Historical Site Assessment Report, March 2000:
Sections 7.1 and 7.2, pp. 27-40

SNEC Soil Characterization Report, May 1995
Pp. 1-7, Appendices 1, 3 & 4

Off-site Laboratory Analyses

(BWXT Technologies, Inc.)

Report #: 0011042	CV Concrete Samples	Report Date: 12/14/00
Report #: 0102059	CV Tunnel Sediment	Report Date: 03/26/01
Report #: 0101037	SSGS Soil Bag Sample	Report Date: 02/22/01
Report #: 0104005	North CV Yard Soil Bag #34L	Report Date: 05/21/01
Report #: 0104079	Well OW-6	Report Date: 05/28/01
Report #: 0106103	Weir Line Sediment Sample	Report Date: 08/09/01

(Teledyne Brown)

Report #: 38251	CV Yard Grid F-8 Soil	Report Date: 05/16/00
Report #: 38252	CV Yard Grid G-8) Soil	Report Date: 05/17/00
Report #: 38250	CV Yard Grid F-7 Soil	Report Date: 05/08/00
Report #: 16599	Discharge Tunnel 6" Drain Line Scraping	Report Date: 07/22/99
Report #: 38253	SSGS East Turbine Sump Area AV-133	Report Date: 05/05/00
Report #: 38254	SSGS Intake Tunnel AT-139	Report Date: 06/08/00
Report # 14181	Well Water Composite (SX-GW-MW-GEO)	Report Date: 09/18/99

(ERL)

Report # 88236	Weir Pipe Sediment (70' from weir to river)	Report Date: 05/07/96
Report # 111151	Composite Spray Pond Soil 125, 126, 127	Report Date: 10/28/99
Report # 111158	Soil Sample SX9SL99202	Report Date: 11/17/99
Report # 115374	SSGS Footprint, Well # 7 Sediment	Report Date: 08/24.00
Report # 113454	SSGS East Sump Sediment @25'	Report Date: 04/25/00

Report # 109430	Discharge Tunnel Wall Scraping	Report Date: 07/29/99
Report # 111156	SSGSDT Seal Chamber #3 Sediment	Report Date: 11/17/99
Report # 111155	SSGSDT Seal Chamber @40' Sediment	Report Date: 11/17/99
Report # 111152	SSGSDT 16" Pipe Internal @ 138'	Report Date: 11/17/99
Report # 111157	SSGSDT Floor Sediment @ 32'	Report Date: 11/17/99
Report # 111153	SSGSDT 8" & 15" Pipe Internal Composite	Report Date: 11/17/99
Report # 111154	SSGSDT Floor Sediment Composite	Report Date: 11/17/99
Report # 109067	Well Water Composite (SX-GW-MW-GEO)	Report Date: 09/30/99
Report # 114218	SSGS Well #2-Sediment, W. Turbine Sump	Report Date: 06/05/00
Report # 114219	SSGS Well #3 Sediment, Collection Tank	Report Date: 06/06/00
Report # 114221	SSGS DT 18" Line	Report Date: 05/24/00

Survey Request (SR) & Site Work Instruction (SWI) Sample Results

SR-0004	SSGS East ~790' to 811' Elevation.
SR-0006	SSGS West ~790' to 811' Elevation
SR-0007	Open Land Areas Near SSGS Tunnels
SR-0008	Northeast End of SSGS Discharge Tunnel
SR-0011	SSGS Center Section ~790' to 811' Elevation
SR-0012	SSGS Firing Isle, 806' Elevation
SR-0013	Discharge Tunnel Seal Chambers
SR-0014	SSGS Spray Pump Pit
SR-0015	SSGS Miscellaneous (Shunt Line, Weir Line, SSGS Sump Cross Connecting Lines & SSGS Intake Tunnel.
SR-0024	SSGS Boiler Pad at 811' Elevation
SWI-99-069	SSGS Discharge Tunnel

d. Deselect radionuclides < 1% of media mix and < 10% of the dose limit per NUREG-1727, Appendix E. From the 19 radionuclides determined in Section C above, 8 radionuclides (Fe-55, Ni-59, Nb-94, Tc-99, Eu-154, Pu-242, Cm-242 & Cm-244) were further deselected due to a low abundance (< 1%) in the media mixes. In the 1996 Site Characterization Report, Table 4-1, Fe-55 was listed as 2.46% of the site's radionuclide inventory contained within the steel structures of the reactor vessel. In 1998 the reactor vessel was removed along with the steam generator and pressurizer as part of the Large Component Removal program. This program essentially reduced the Fe-55 to only 0.12% of the site inventory per the 2000 LTP, Table 2-1.

Table 5 provides an analysis of how these radionuclides were deselected. Dose conversion factors were taken from Federal Guidance Report (FGR) 12, Table III-7 (Dose Coefficients for Exposure to Soil Contaminated to an Infinite Depth). Since these radionuclides are < 1% of the mix the applicable DCFs were adjusted down by 0.01. These radionuclides were then compared against Cs-137 (the predominant radionuclide on the site) to determine if the respective doses were greater than 10% of the Cs-137 dose. Since there were no DCFs for Fe-55 and Ni-59 in FGR 12, FGR 11, Tables 2.1 (Exposure-to-Dose Factors for Inhalation) and 2.2 (Exposure-to-Dose Factors for Ingestion) were used. The same dose analysis was performed for these two radionuclides. This reduced to a final list of 11 radionuclides (H-3, C-14, Co-60, Ni-63, Sr-90, Cs-137, Eu-152, Pu-238, Pu-239, Pu-241 & Am-241) that are considered present at SNEC.

e. Evaluate locations where radionuclides have been identified on site and are most likely to occur (e.g. inside or outside the CV). From review of the different types of media from Section C and Table 1, it can be shown that all 11 radionuclides have the potential to be present inside the CV. However, for media (e.g. soil, water, concrete, metal) outside the CV the presence of these radionuclides can be more limited.

5. Conclusions

5.1 Based on the radionuclide deselection process, per the guidance in the subject NUREGs, the SNEC Radionuclide List Table in Section 2 lists the potential radionuclides of concern at SNEC. In addition, this is supported by recent characterization data that has been gathered from operational and decommissioning survey work over the last 5 years.

5.2 It is recommended that a total of eleven (11) radionuclides should be analyzed for all collected media and surveyed surfaces inside the CV. The revised radionuclide list should be updated into the next revision of the LTP. For media and surfaces surveyed in land areas and structures outside the CV it is recommended a review of the latest characterization data be used to select the applicable radionuclides of concern for the final site survey.

6. Appendices

6.1 Table 1 – Radionuclide Analysis Results (Laboratory)
6.2 Table 2 – Uranium Ratios
6.3 Table 3 – Uranium Ratios in Nature
6.4 Table 4 - Radionuclide Deselection List
6.5 Table 5 – Radionuclides <10% Dose Impact

Appendix 1

Table1

Radionuclide Analysis Results (Laboratory)

Area	Date	Am-241	C-14	Co-60	Cs-137	H-3	Ni-63	Eu-152	Pu-238	Pu-239	Pu-240	Pu-241	Sr-90	U-234	U-235	U-238	K-40	Ra-226	Th-232	Th-228
Proposed DCGL (pCi.g)		1.5	3.7	2.5	8.5	260	1700	6.3	24	22	22	45	1.6	18	1.2	30	N/A	N/A	N/A	N/A
SSGS Intake Tunnel AT-139	6/8/00		1.8		0.22									0.65		0.45	9.79	1.06		
SSGSDT Seal Chamber #3 Sediment	11/17/99				43					0.0071				2.7	0.063	1.9				
SSGSDT Seal Chamber @40' Sediment	11/17/99				1.9					0.009				0.5	0.0096	0.41				
SSGSDT 16" Pipe Internal @138'	11/17/99				3.8					0.02				4.5	0.097	2.8				
SSGSDT Floor Sediment @32'	11/17/99	0.021			27				0.0037	0.012				2.3	0.062	1.7				
SSGSDT 8" & 15" Pipe Internal Comp. (160&163')	11/17/99				2.2					0.0081				1.6	0.031	1.1				
SSGSDT Floor Sediment Composite @100 & 326'	11/17/99	0.035			7					0.0042				1.6	0.031	1.1				
SSGS Footprint E. Turbine Area AV-133 (pumped)	6/5/00			0.37	97.8									1.1		0.57	2.58	0.326		
SSGS Footprint Well #7 Pumped Sediment	8/24/00			1.5	77									0.93	0.029	0.83				
SSGS E. Sump Sediment @25', AV183, Well #1	4/25/00	0.088			85									0.88	0.052	0.85				
Discharge Tunnel Wall Scraping	7/29/99			0.84	120									1.2		0.74	1.7			
Discharge Tunnel 6" Drain Line Scraping	7/22/99	5.4		30	4800		55		1.6	2.5	2.5			0.45		0.57	39.8			
SSGS Soil Bag #5	11/22/00			0.4	11.4									0.198	0.009	0.193				
Composite of Spray Pond Soil 125, 126 & 127	11/28/99	0.0035							0.0043					0.56	0.015	0.41				
SX9SL99202 (Subsurface #11 (4-6'))	11/17/99	0.012												0.45	0.014	0.4				
CV Tunnel Sediment	2/14/01			1.26	1250								9.67	1.12		1.46				
Weir Pipe Sediment ~70' out toward river from weir	5/7/96			0.51	46												4.3		0.54	
North CV Yard Soil Bag #34L	3/26/01	0.07		1.31	5.04				0.02	0.04	0.04		0.27	0.34	0.02	0.31				
CV Yard F-7, Loc #2, Truck R-2	5/8/00			0.175	210									0.36		0.24	16.7	1.19	1.49	
CV Yard R-2-4 (G-8) AZ-129	5/17/00			0.084	555	110								0.33		0.25	16.8	0.952	1.33	
CV Yard Grid #F-8 AY-129	5/16/00			0.104	612									0.38		0.28	20.4	1.11	1.55	
Sediment Westinghouse Lab Pad Drain Line Comp.	3/27/00	0.092		0.067	6.8									1	0.041	0.85	12	3	1.3	
Soil	10/13/94			0.228	11.9												12.6	2.34		6.43
1994 Soil Remediation Report Results	11/9/94			0.968	33.1									0.33		0.24	14.6			1.23
1994 Soil Remediation Report Results	11/19/94			2.35	319									0.31		0.23		23.3		
OW-6 Well (pCi/L)	4/25/01													0.52						
OW-4R Well (pCi/L)	4/25/01													1.19		0.84				
OW-5R (pCi/L)	4/25/01													2.38		2.1				
OW-3 (pCi/L)	4/25/01													0.49						
OW-3R (pCi/L)	4/25/01													0.94		0.44				
Weir Line 135' above river outlet	5/24/01				61.6									0.7	0.02	0.53				
CV Concrete (SX-01-CW-00-574)	10/18/00		33.62	0.04	1.37	40.86		0.1				275								
CV Concrete (SX-01-CW-00-637)	10/23/00	0.55	115		58.5	191						31.04								
CV Concrete (SX-01-CW-00-636)	10/27/00		22.4		5.08	66.6						46.78								
CV Concrete (SX-01-CW-00-626)	10/27/00	1.08	90.29		0.55	270.87						39.69								
CV Concrete (SX-01-CW-00-638)	10/18/00		67.48		11.1	225.26						23.52								
CV Concrete (SX-02-CW-00-639)	11/7/00		80.42		0.21	376.21						28.76								
CV Concrete (SX-02-CW-00-640)	5/25/95		98.39		27.7	518.57						10.07								
Discharge Tunnel Sediment (1st Seal ChamberCrud Pile 3" Vertical Drain Line)	7/22/99				67									0.72		0.68	2.4		0.33	
Discharge Tunnel Sediment -End of Tunnel (H3 in pCi/L)	7/21/99				21.2	210								0.28		0.38				
SSGS Footprint Collection Tank Area Aw-132/SSGS Well #3 Sediment					5.5									0.34		0.31	6.1			
SSGS DT 18" Line Sediment	5/24/00				3.1									1.1	0.029	0.84	9.3	4.8	2	

Note: Activity is specified as pCi/g unless specified otherwise.

Appendix 2

Table 2
Uranium Ratios

	U-234*	U-235*	U-238*	U234/238 Ratio	U238/U235 Ratio
SSGS Intake Tunnel AT-139	0.65		0.45	1.4	
SSGSDT Seal Chamber #3 Sediment	2.7	0.063	1.9	1.4	30.2
SSGSDT Seal Chamber @40' Sediment	0.5	0.0096	0.41	1.2	42.7
SSGSDT 16" Pipe Internal @138'	4.5	0.097	2.8	1.6	28.9
SSGSDT Floor Sediment @32'	2.3	0.062	1.7	1.4	27.4
SSGSDT 8" & 15" Pipe Internal Comp. (160&163')	1.6	0.031	1.1	1.5	35.5
SSGSDT Floor Sediment Composite @100 & 326'	1.6	0.031	1.1	1.5	35.5
SSGS Footprint E. Turbine Area AV-133 (pumped)	1.1		0.57	1.9	
SSGS Footprint Well #7 Pumped Sediment	0.93	0.029	0.83	1.1	28.6
SSGS E. Sump Sediment @25', AV183, Well #1	0.88	0.052	0.85	1.0	16.3
Discharge Tunnel Wall Scraping	1.2		0.74	1.6	
Discharge Tunnel 6" Drain Line Scraping	0.45		0.57	0.8	
SSGS Soil Bag #5	0.198	0.009	0.193	1.0	21.4
Composite of Spray Pond Soil 125, 126 & 127	0.56	0.015	0.41	1.4	27.3
SX9SL99202 (Subsurface #11 (4-6'))	0.45	0.014	0.4	1.1	28.6
CV Tunnel Sediment	1.12		1.46	0.8	
Weir Pipe Sediment ~70' out toward river from weir					
North CV Yard Soil Bag #34L	0.34	0.02	0.31	1.1	15.5
CV Yard F-7, Loc #2, Truck R-2	0.36		0.24	1.5	
CV Yard R-2-4 (G-8) AZ-129	0.33		0.25	1.3	
CV Yard Grid #F-8 AY-129	0.38		0.28	1.4	
Sediment Westinghouse Lab Pad Drain Line Comp.	1	0.041	0.85	1.2	20.7
Soil					
1994 Soil Remediation Report Results	0.33		0.24	1.4	
1994 Soil Remediation Report Results	0.31		0.23	1.3	
OW-6 Well (pCi/L)	0.52				
OW-4R Well (pCi/L)	1.19		0.84	1.4	
OW-5R (pCi/L)	2.38		2.1	1.1	
OW-3 (pCi/L)	0.49				
OW-3R (pCi/L)	0.94		0.44	2.1	
Weir Line 135' above river outlet	0.7	0.02	0.53	1.3	26.5
Discharge Tunnel Sediment (1st Seal ChamberCrud Pile 3" Vertical Drain Line)	0.72		0.68	1.1	
Discharge Tunnel Sediment -End of Tunnel (H3 in pCi/L)	0.28		0.38	0.7	
SSGS Footprint Collection Tank Area Aw-132/SSGS Well #3 Sediment	0.34		0.31	1.1	
SSGS DT 18" Line Sediment	1.1	0.029	0.84	1.3	29.0
Average				1.3	27.6

*** Activity is in pCi/g unless specified otherwise.**

Appendix 3

Table 3

Uranium Ratios in Nature

Radionuclide	Half-Life (Years)	Abundance in nature	λ	N	Activity in nature (disintegrations/yr/gm)
U-234	2.47E+05	0.000057	2.81E-06	2.57E+21	4.11E+11
U-235	7.10E+08	0.007196	9.76E-10	2.56E+21	1.80E+10
U-238	4.51E+09	0.99276	1.54E-10	2.53E+21	3.86E+11

Specific Activity (A)= λN(%) where: $\lambda = .693/t_{1/2}$, N=atoms/mole(gm), %=fractional abundance in nature
Avogadro Constant (atoms/mole) = 6.02E+23 atoms/mole

Nuclide Ratio	Ratio in nature	Ratio w/ +/- 50% uncertainty range *
U234/U238	1.1	**0.55 - 1.65**
U238/U235	21.4	**10.7 - 32.1**
U234/U235	22.9	**11.45 - 34.35**

* Calculated to account for analytical uncertainties.

Reference: Radiological Health Handbook, Section IV, January 1970.

Appendix 4

Table 4
Radionuclide Deselection List

Isotope	Half Life (y)	Bioshield Concrete[1,2]	Rebar [3]	Surface Contamination[4]	Activated Reactor Components[5]	Release Deposits[6]	Half Life >3.0 y [7]	Isotopes Detected @SNEC >MDA	Isotopes @SNEC > 1% of Mix [8]
H-3	1.24E+01	Y	Y				Y	Y	Y
C-14	5.73E+03	Y	Y		Y		Y	Y	Y
Na-22	2.60E+00	Y							
P-33	6.96E-02	Y							
S-35	2.40E-01	Y							
Cl-36	3.01E+05	Y	Y				Y		
Ar-37	9.50E-02	Y							
Ar-39	2.65E+02	Y					Y		
Ca-41	1.40E+05	Y	Y				Y		
Ca-45	4.47E-01	Y							
Sc-46	2.30E-01	Y							
Cr-51	7.59E-02	Y		Y		Y			
Mn-53	3.70E+06	Y	Y				Y		
Mn-54	8.56E-01	Y	Y	Y	Y	Y			
Fe-55	2.70E+00	Y	Y	Y	Y			Y	
Fe-59	1.22E-01	Y		Y	Y	Y			
Co-57	7.42E-01					Y			
Co-58	1.94E-01	Y		Y	Y	Y			
Co-60	5.27E+00	Y	Y	Y	Y	Y	Y	Y	Y
Ni-59	7.51E+04	Y	Y		Y		Y	Y	
Ni-63	9.20E+01	Y	Y		Y		Y	Y	Y
Zn-65	6.68E-01	Y	Y		Y				
Se-79	6.50E+04	Y	Y				Y		
Sr-89	1.38E-01			Y		Y			
Sr-90	2.91E+01	Y	Y	Y		Y	Y	Y	Y
Y-90	7.31E-03			Y		Y			
Nb-92m	3.60E+07	Y	Y				Y		
Nb-93m	1.36E+01	Y					Y		
Nb-95	3.50E+01	Y		Y	Y	Y	Y		
Zr-93	1.53E+06	Y	Y				Y		
Mo-93	3.50E+03	Y	Y		Y		Y		
Nb-94	2.03E+04	Y	Y		Y		Y	Y	
Zr-95	1.75E-01			Y	Y	Y			
Tc-99	2.13E+05	Y	Y				Y	Y	
Ru-103	1.08E-01					Y			
Ag-108m	1.27E+02	Y	Y				Y		
Ag-110m	6.85E-01					Y			
Sn-121m	5.50E+01	Y	Y				Y		
Sb-124	1.65E-01					Y			
Sb-125	2.77E+00					Y			
Te-129m	9.21E-02			Y					
I-129	1.57E+07	Y	Y				Y		
I-131	2.20E-02			Y		Y			
I-133	2.37E-03					Y			
Ba-133	1.07E+01	Y	Y				Y		
Cs-134	2.06E+00	Y	Y	Y		Y			
Cs-135	2.30E+06	Y	Y				Y		
Cs-136	3.59E-02			Y		Y			
Cs-137	3.00E+01	Y	Y	Y		Y	Y	Y	Y
Ba-140	3.49E-02					Y			
La-140	4.60E-03					Y			
Ce-141	8.90E-02					Y			
Ce-144	3.77E-03					Y			
Pm-145	1.77E+01	Y	Y				Y		
Sm-146	1.03E+08	Y	Y				Y		
Sm-151	9.01E+01	Y	Y				Y		
Eu-152	1.27E+01	Y	Y				Y	Y	Y
Eu-154	1.60E+01	Y	Y				Y	Y	
Eu-155	1.81E+00	Y	Y						
Tb-158	1.50E+02	Y	Y				Y		
Ho-166m	1.20E+03	Y	Y				Y		
Hf-178m	3.10E+01	Y	Y				Y		
Pb-205	1.43E+07	Y	Y				Y		
U-233	1.59E+05	Y	Y				Y		
Pu-238	8.78E+01						Y	Y	Y
Pu-239	2.41E+04	Y	Y				Y	Y	Y
Pu-241	1.32E+01						Y	Y	Y
Pu-242	3.79E+05						Y	Y	
Cm-242	4.40E-01							Y	
Cm-244	1.76E+01						Y	Y	
Am-241	4.58E+02						Y	Y	Y

Footnotes:
1. NUREG/CR-0130, Volume 1, Table 7.3-5, "Radioactivity Levels at the Inner Surface of the Activated Biological Shield at Reactor Shutdown"
2. NUREG/CR-3474, Table 5.4, "Activation of PWR Bioshield (Ci/gm) Average Concrete 30 EFPY at Core Axial Midplane"
3. NUREG/CR-3474, Table 5.6, "Activation of PWR Bioshield (Ci/gm) Average Rebar 30 EFPY at Core Axial Midplane"
4. NUREG/CR-0130, Volume 1, Table 7.3-11, Isotopic Composition of Accumulated Surface Contamination in the Referenced PWR..."
5. NUREG/CR-0130, Volume 2, Table C.1-3, "Radioactivity Levels in Major Activated Reactor Components at Time of Reactor Shutdown"
6. NUREG/CR-0130, Volume 1, Table 7.3-14, "Est. Accumulated Activity of Radionuclides Deposited on the PWR Site ...."
7. SNEC shutdown 30 years. Isotopes with a half life <3.0 years and therefore, <0.1% of original activity (i.e. decayed 10 half lives) were deselected.
8. Listed isotope includes daughter(s).

Appendix 5

Table 5
Radionuclides <10% Dose Impact

Effective Dose Equivalent

	FGR #12 Table III-7				
Isotope	Sv m^3/Bq s	mrem g/pCi y	1% Correction	% of Isotope x to Cs-137	<10% of dose? (Y/N)
Fe-55	0.00E+00	0.00E+00	0.00E+00	0.00%	n/a
Ni-59	0.00E+00	0.00E+00	0.00E+00	0.00%	n/a
Nb-94	5.18E-17	9.68E+00	9.68E-02	2.68%	y
Tc-99	6.72E-22	1.26E-04	1.26E-06	0.00%	y
Eu-154	4.11E-17	7.68E+00	7.68E-02	2.13%	y
Pu-242	6.85E-22	1.28E-04	1.28E-06	0.00%	y
Cm-242	9.15E-22	1.71E-04	1.71E-06	0.00%	y
Cm-244	6.74E-22	1.26E-04	1.26E-06	0.00%	y
Cs-137	1.93E-17	3.61E+00			

Ingestion

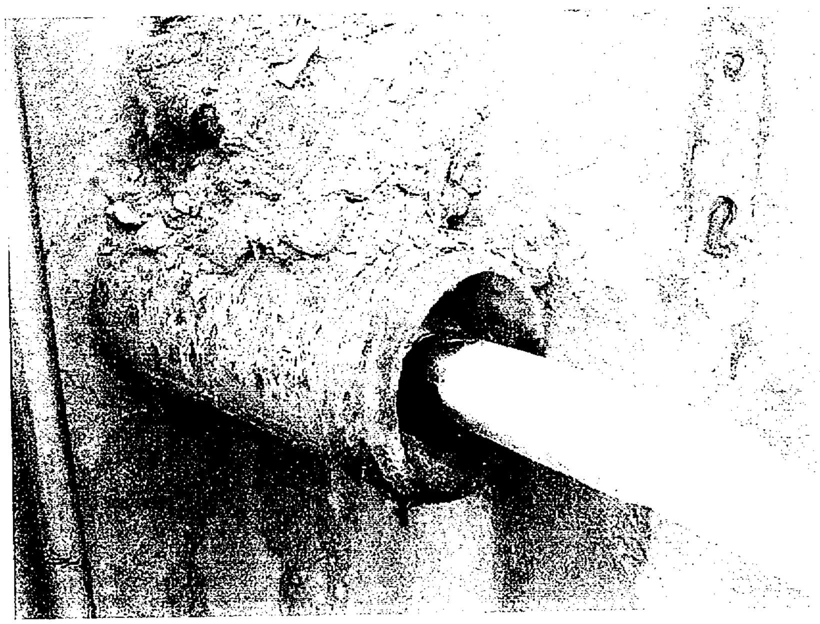
	FGR#11 Table 2.2				
Isotope	Sv/Bq	mrem/pCi	1% Correction	% of Isotope x to Cs-137	<10% of dose? (Y/N)
Fe-55	1.64E-10	6.07E-07	6.07E-09	0.01%	y
Ni-59	5.67E-11	2.10E-07	2.10E-09	0.00%	y
Cs-137	1.35E-08	5.00E-05			

Inhalation

	FGR#11 Table 2.1				
Isotope	Sv/Bq	mrem/pCi	1% Correction	% of Isotope x to Cs-137	<10% of dose? (Y/N)
Fe-55	7.26E-09	2.69E-05	2.69E-07	0.84%	y
Ni-59	3.58E-10	1.32E-06	1.32E-08	0.04%	y
Cs-137	8.63E-09	3.19E-05			

Embedded Pipe Radiation Survey Report

GPU Nuclear Corp.
Saxton Experimental Nuclear Co.
Saxton, Pa.



By:

CoPhysics Corporation
1242 Route 208
Monroe, NY 10950

Site Work: October 2001
Report: January 2002

Contacts:

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Theodore Rahon, CoPhysics Corporation (845-783-4402)

CONTENTS

1.0 INTRODUCTION

During October 2001, personnel from CoPhysics Corporation and GPU Nuclear performed *in situ* gamma spectroscopy measurements and scale/sediment sampling as part of study of radioactive contamination in embedded piping, on the site of the Saxton Nuclear Experimental Corporation (SNEC) Facility. 127 spectra were collected in approximately 10 pipes and drainage areas. Additionally, 39 QA/QC measurements were performed, and 29 scale/sediment samples were collected and analyzed in the on-site GPU laboratory.

2.0 OBJECTIVE

The objective of the survey was to measure gamma-emitting radionuclides (cesium-137 and cobalt-60) that may have been deposited in pipes and drains in and around the former coal plant via connections with the SNEC nuclear plant. The data are to be used as part of the site Final Status Survey and thus the sensitivity of the method must provide a minimum detectable activity sufficient to prove that release criteria are met.

3.0 SURVEY METHODOLOGY

3.1 General Survey Approach

GPU personnel specified several pipes and drain systems on the property that were thought to be relatively free of contamination and may be releasable (see site drawing below). Scraping samples were collected from the end of each pipe, if accessible. A NaI detector was then inserted into each pipe and gamma spectra were collected at various distances along the pipe length. Cesium-137 and cobalt-60 count rates were obtained from each spectrum and a surface activity (dpm/100 sq.cm) was calculated from the detector and pipe geometry parameters and the MicroShield[1] computer code.

The *in situ* gamma spectroscopic approach is best suited to provide results in activity per unit area (surface activity) or total activity per pipe. However, for comparison with sampling results, the *in situ* method was also used to estimate the radionuclide concentration (in pCi/g) in scale and sediment. This involved the dividing of the surface activity by an estimate of the scale thickness. However, the accuracy of such concentration results is most reliant upon field estimates of pipe scale thickness, which may be rather uncertain.

Both the *in situ* and sampling techniques have their advantages and disadvantages. Sampling provides a more accurate assessment of a radionuclide concentration in a single sample volume than the *in situ* measurement method. However, sampling alone does not provide a more accurate assessment of total activity per pipe length because in sampling, the fraction of

[1] MicroShield radiation shielding computer code is a product of Grove Engineering, Rockville, MD.

contaminated material actually sampled and the degree the sample is representative of the total volume of sampled materials is normally not known accurately.

3.2 Release Limits

GPU Nuclear is currently re-evaluating applicable site volumetric DCGL values (concentrations) using the dose modeling computer code RESRAD[2] version 6.1. The volumetric DCGL values for Cs-137 and Co-60 are expected to fall within the ranges specified in Table 3.2.

The original SNEC Facility surface DCGL values were assembled from US NRC default values developed using the US NRC's dose modeling computer code DandD. These surface limits will continue to be valid in the latest version of the SNEC Facility License Termination Plan (LTP). These surface activity DCGL's are also shown in Table 3.2.

Table 3.2 – Applicable DCGL's

	Surface Area (dpm/100 cm^2)	Open Land Areas (pCi/g)
Cs-137	28,000	> 8.5
Co-60	7,000	> 2.5

How the above DCGL values apply to embedded piping is not presently clear. Very thin layers of contamination in piping are essentially surface contamination. However, thicker layers, clogged piping, or sediment in sumps could be considered to be soil. Furthermore, most of the piping is underground and thus could be considered part of an open land area, survey unit.

If the embedded piping is considered to be part of an open land area, then the definition of the mass associated with the contamination is very important in calculating a concentration. To calculate a concentration, the contamination on the inner surface of a pipe could be divided by the mass of the entire pipe or by the mass of the scale alone. Additionally, if considered to be open land area contamination, the volume of these piping systems are extremely small with respect to the RESRAD surface soil area model of 10,000 square meters (upper 1 meter of soil at the site). The application of any reasonable area factor should then permit larger concentrations within these small volumes.

In this report, the activity measured is initially treated as surface activity contaminating the interior surface of the pipe or sump. Then, the thickness of the scale is estimated from visual observation. If no scale was visible, a 1/4" thickness was assumed. The radionuclide concentration is then calculated by dividing the surface activity by the estimate of scale thickness. This is a much more conservative approach than using the entire mass of the pipe as the divisor.

[2] RESRAD dose modeling computer code is a product of Argonne National Laboratories, Argonne, Illinois.

3.3 Instrumentation

The following instrumentation was used during gamma measurements:

- Portable multichannel analyzer (Aptec Model 5004 MCA), power supply (Aptec Model AH1PC), computer (generic portable PC)
- 1" x 4" NaI(Tl) gamma radiation detector (Alpha Spectra, Inc. Model i16/1.5B, Serial #110999B)

The 1 x 4" NaI gamma detector was protected by a 2" diameter, 18" long PVC housing. The 2" PVC housing was fitted with a threaded coupling to allow 1" diameter extensions to be added so that up to 30 feet of pipe could be surveyed during one insertion. Gamma spectroscopy measurements commenced in each pipe or sump by inserting the NaI detector into the pipe/sump either with or without a centering device, depending on pipe conditions.

A spectrum was then acquired for sufficient time to achieve a minimum detectable activity (MDA) of 1 cps or less in the cesium-137 region. Counting times ranged from 5 to 10 minutes. The minimum detectable activity of 1 cps for ^{137}Cs corresponds to about 400-dpm/100 cm^2 in a typical iron, yard drainpipe. MDA's for ceramic pipes, which contain elevated levels of naturally occurring radium and thorium, are higher, approximately 800-dpm/100 cm^2. Nominal concentration-based MDA's (in pCi/g) cannot be quoted because they are more dependent upon the mass of scale present, than detector capability. See the actual results for pipe-specific concentration MDA's.

3.4 Calibration

The NaI detector was exposed to NIST-traceable radionuclide standards in the laboratory and in the field to determine its intrinsic efficiencies. The resultant intrinsic efficiencies were:

- 0.39 counts per Cs-137 gamma (662 keV) ($\pm$ 6%)
- 0.17 counts per Co-60 gamma (1332 keV) ($\pm$ 6%)

Calibration certificates of the NIST-traceable standards are shown in Appendix E.

3.5 Pipe/Drain Preparation

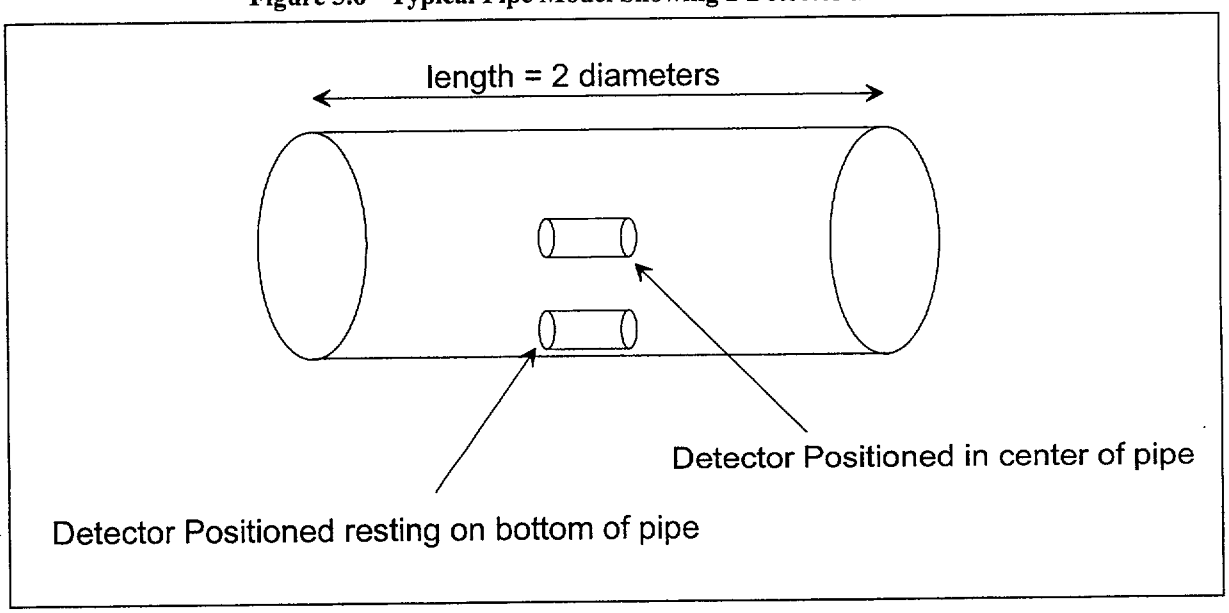
Pipes were unearthed and broken open if not already accessible. Sediment was manually removed from sumps and yard drains before *in situ* measurements were performed (see photographs in Appendix A).

3.6 Source Modeling

During measurements, each detector-pipe geometry was recorded, for example, "detector centered in a 7.5" diameter pipe", or "detector resting on bottom of 12" diameter, horizontal pipe". Each such geometry was later modeled using the MicroShield computer code (ref. Grove Engineering, Inc., Version 5.05-00121). MicroShield was used to calculate the expected photon fluence from various geometries (models) of pipe or sump contamination. .

Normally, each pipe model assumed a thin layer 0.64-cm (1/4") of contaminated scale coating the inner surface of the pipe. This was the typical scale thickness found in cast iron pipes at the SNEC site. The scale is assumed to be made up of iron, with a density of 2 g/cc. The scale is assumed to cover the full inner surface of the pipe section measured. Sump models assumed 2.54 cm (1") of sediment (density of 1.6 g/cc) on the floor of the sump. The 42" diameter Shunt Line was modeled as having a 1-foot wide x 1" deep layer of sediment along its bottom, with 1/2" of overlaying water.

Figure 3.6 - Typical Pipe Model Showing 2 Detector Positions



The length of each pipe was modeled as 2 diameters, with the dose point (detector) placed half way along the length, either centered in the middle of the pipe diameter or resting on the bottom of the pipe wall (see Figure 1). If the contamination is uniformly distributed over the inner surface area or is concentrated along the bottom of the pipe, greater than 90% of the detector count rate will be due to activity within a 2-diameter length of pipe section.

The result of the MicroShield analysis is the gamma fluence rate in MeV/(cm^2-sec) at the dose point, or detector. After division by the gamma-ray energy and the surface activity used, the activity to gamma flux conversion factor is calculated in units of gammas/(cm^2-sec) at the detector per uCi/cm^2 on the inner surface of the pipe.

After multiplying by the detector intrinsic efficiency times the cross sectional area and applying unit conversions, the count rate to activity conversion factors are calculated in units of cps per dpm/100 cm^2 for each geometry used. The activity conversion factors then are used to convert detector count rates into activities as discussed in the following section.

A list of models used is shown in Appendix C.

3.7 Techniques For Reducing/Evaluating Data

3.7.1 Spectrum Analysis

After the field work was complete, each spectrum was reviewed and analyzed as follows:

- Energy calibration (keV per channel) was checked and adjusted as necessary to account for temperature-based gain shifts. Note that the counting efficiencies do not change with temperature. Only the energy calibration changes, i.e., the location of the photopeaks. To correct for this, the naturally-occuring photopeaks (K-40, Bi-214, annihilation, etc.) in each spectrum as well as Cs-137 (if detectable) were used to perform an energy re-calibration if necessary.
- Regions of interest (ROI's) were then set up for Cs-137 (575 to 715 keV), Co-60 (1270 to 1390 keV), and radium-226 progeny (1650-1850 keV). The gross and net counts for the Cs-137 and Co-60 ROI's as well as the gross counts for the radium progeny ROI were recorded in a spreadsheet database. (see Spectrum A below for examples of ROI's.)
- The contribution from background radionuclides to the Cs-137 and Co-60 ROI's were estimated from the radium progeny ROI of each spectrum and then subtracted from the ROI's of interest. This removed the radium-226 progeny (609 keV) contribution to the Cs-137 ROI and also reduced the K-40 contribution to the Co-60 ROI.
- The adjusted net count rates for each ROI were calculated in the spreadsheet database. The spreadsheet was used to apply the activity conversion factors to calculate the radionuclide surface activities, their uncertainties, and the minimum detectable activities (MDA's) as discussed in following sections.
- The radionuclide concentrations in the scale were also estimated by multiplying the surface activity by an estimate of the scale thickness in each pipe or sump.
- 13 background spectra were used to estimate the contribution of radium progeny and other background radionuclides to the Cs-137 and Co-60 ROI's. The designated radium progeny ROI (1650-1850 keV) contained the 1764 keV Bi-214 photopeak as well as Compton background from thorium-232 progeny. The ratio of the radium progeny ROI to the Cs-137 and Co-60 ROI's were calculated from the averages of the background spectra. These ratios were used in the spreadsheet to correct each spectrum for the presence of radium and thorium.

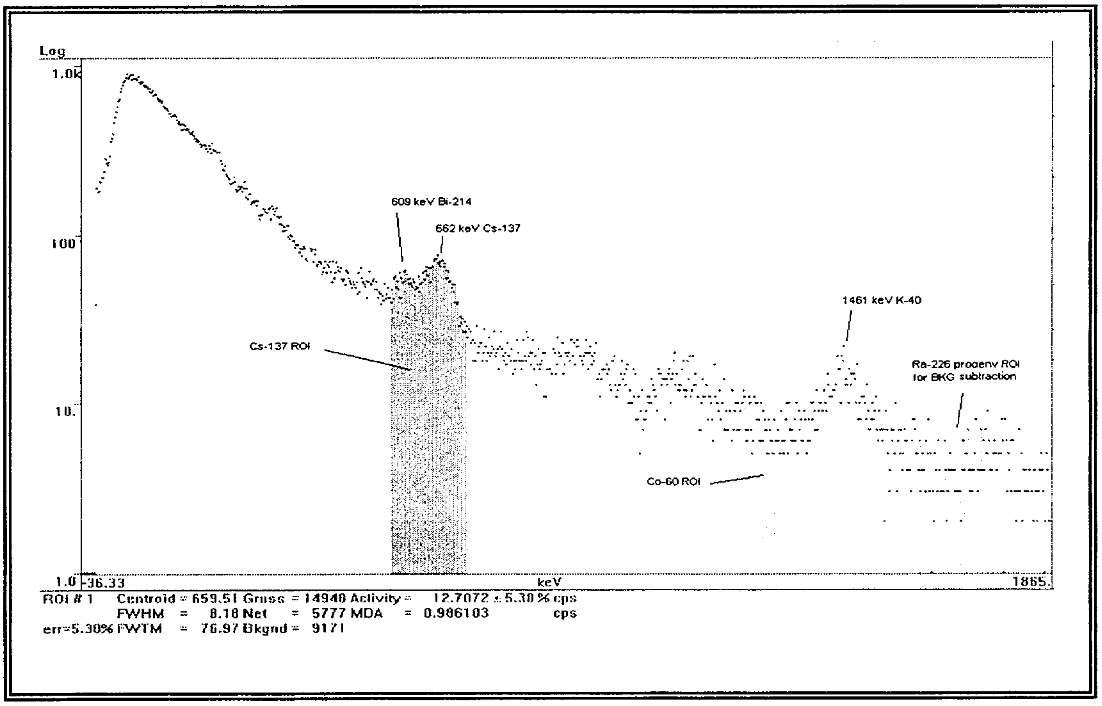


Figure 3.7 - Example Gamma-ray Spectrum

3.7.2 Radioactivity Calculation

The net count rates in the Cs-137 and Co-60 ROI's were adjusted for the contribution from background radionuclides and divided by their respective conversion factors to calculate the average Cs-137 and Co-60 activities in the pipe scale of sump sediment.

The calculation used is shown below:

$$\text{Surface Activity} = (ROI_{NET} - ROI_{RA} * FAC) / (T * CONV)$$

Where:

- ROI_{NET} = sample spectrum ROI net counts
- ROI_{RA} = estimated background radionuclide contribution to sample ROI
- FAC = factor to estimate the radium contribution to the Cs-137 or Co-60 ROI = Cts in ROI of interest / cts in ROI_{RA}
- T = Sample spectrum live time (sec): Assume background-counting time = Sample counting time (conservative assumption).
- CONV = count rate to activity conversion factor (cps per dpm/100 cm^2)

The resulting surface activity results and concentration estimates are shown in Appendix A.

3.7.3 Uncertainty Calculation

There are 2 background subtraction steps involved in the calculation of soil concentration: the subtraction of background due to background radionuclides and the subtraction of the Compton continuum under the photopeaks. The uncertainty due to this 2-step background subtraction process involves the summation of the variances of the individual uncertainties. In addition, a rough estimate of general systematic uncertainty (10 %) to account for model uncertainty, soil density variability, detector angular response, etc. was added to the Poisson uncertainty. This overall uncertainty was estimated using the following formula:

$$\text{2-sigma Uncertainty} = 2 * \text{SQRT}\ (|ROI_{GR}|+|ROI_{BK}|+|ROI_{RA}|*FAC + ENDPT_{BK}) / (T * CONV) + SYS$$

Where:

ROI_{GR} = sample spectrum ROI gross counts
ROI_{BK} = sample spectrum ROI background counts
ROI_{RA} = estimated background radionuclide contribution to sample ROI
FAC = factor to estimate the radium contribution to the Cs-137 or Co-60 ROI
= cts in ROI of interest / cts in ROI_{RA}
T = Sample spectrum live time (sec): Assume background-counting time = Sample counting time (conservative assumption).
$ENDPT_{BK}$ = adjusted ROI endpt counts used to estimate Compton bkg line under peak
= (4 ch * .069 cps/lower ch + 4 ch * .039 cps/upper ch)*T for Cs-137 ROI; and (4 ch * 0.017 cps/lower ch + 4 ch * 0.014 cps/upper ch)*T for Co-60 ROI
CONV = count rate to activity conversion factor
(cps per dpm/100 cm^2 or cps per pCi/g)
SYS = other systematic uncertainties =~ 10% of the result

3.7.4 MDA Calculation

The minimum detectable activity (MDA) for Cs-137 and Co-60 in NaI-based gamma spectrometry is dependent on the detector efficiency, counting time and the quantity of interfering (i.e., background) radionuclides in the sample spectrum. For this project, the effect of interfering radionuclides (radium & progeny, K-40 etc.) is estimated by use of the radium progeny ROI (1600 to 1800 keV). These parameters are included in the following equation to calculate MDA:

$$MDA = 4.65 * \text{SQRT}\ (ROI_{SBK}+ROI_{RA} * FAC + ENDPT_{BK}) / (T * CONV)$$

Where: see variable definition in prior section

3.8 Quality Assurance

In-field quality assurance checks included daily check source and background counts. Photopeak shape and resolution were reviewed in the field to ensure that the detector remained in good working order with no physical damage or adverse temperature / moisture effects.

Approximately 5% of the readings were duplicated, totaling 8 measurements. All of the 8 duplicates were within 2 standard deviations of the original measurements.

A listing of quality assurance checks is shown in Appendix F.

4.0 RESULTS AND DISCUSSION

The results of all measurements are shown in Appendix B. A more condensed summary of specific results for each pipe/drain system are redisplayed and discussed in the following sections. Applicable survey diagrams are shown within the sections and photographs of each area are shown in Appendix A.

Also discussed in each section is a comparison of sampling and *in situ* measurement results (concentrations). As discussed earlier, only approximate, not exact, comparisons are appropriate because of several reasons:

1. The sample locations and *in situ* measurement points are not perfectly aligned. That is, scale samples were normally collected at an accessible end or opening into the pipes surveyed, whereas *in situ* measurements were performed at greater depths into the pipes (see notations and/or survey diagrams). While moderate uniformity of radioactivity in a pipe can be expected (i.e., + - factor of 2 or 3), perfect uniformity cannot be expected. In addition, increasing or decreasing concentration levels within piping are commonly observed when approaching or retreating from the source of the contamination within the system.

2. The sampled material was dried before analysis, whereas *in situ* results are presented "as found" in the environment, i.e., normally wet. Drying in the laboratory can concentrate the activity by approximately 20 to 50% over what is actually found in the environment.

3. As discussed earlier in this report, the *in situ* method more accurately measures surface activity rather than concentrations because the concentration estimate requires an estimate of scale thickness in the field, which can increase the overall uncertainty by as much as 50%.

Notwithstanding these basic differences in the sampling and *in situ* methods, most of the compared concentration results are in relatively good agreement (mostly within a factor of 2).

The following sections discuss the radiological status of each drain / pipe individually:

4.1 Boiler Pad Piping

Seven pipes had been dug up from the boiler pad area by GPU and staged on 2 pallets. The pipes were cast iron with diameters ranging from 3.75" to 9.5" and lengths ranging from 5 to 8 feet. One spectrum and one scale sample were collected from each pipe. Laboratory analysis of scale samples and in situ gamma spectroscopy results were in good agreement. All results are well within the previously discussed site DCGL's.

Table 4.1 – Results: Boiler Pad Piping

Measurement #		In situ Gamma Spectroscopic Results (dpm/100 sq.cm) Cs-137	Co-60	(estimated pCi/g) Cs-137	Co-60	GPU Laboratory Sampling Result ID	(pCi/g) Cs-137	Co-60	Description	Note
100801 A	1	< 377	< 244	< 1.3	< 0.9	1510	0.12	<0.09	6" - "South Boiler Pad"	samp 24" from meas pt
100801 B	1	< 359	< 226	< 1.3	< 0.8	1511	<0.09	<0.09	6" - "SSGS 806 East End"	samp 9" from meas pt
100801 C	1	< 355	< 227	< 1.2	< 0.8	1512	0.07	<0.09	8" - "Center"	samp 4" from meas pt
100801 D	1	< 356	< 241	< 1.3	< 0.8	1513	0.28	<0.09	10" - "Center"	samp 9" from meas pt
100801 E	1	< 306	< 209	< 1.1	< 0.7	1514	0.33	< 0.1	8"	samp 12" from meas pt
100801 E	2	< 340	< 208	< 1.2	< 0.7	NoSamp	---	---	---	---
100801 F	1	< 353	< 251	< 1.2	< 0.9	1515	< 1.3	< 1.4	4" - "South Boiler Pad"	samp 18" from meas pt
100801 G	1	< 353	< 248	< 1.2	< 0.9	1516	0.345	< 0.07	4" - "SSGS East End"	samp 7" from meas pt

4.2 Cross-Over Line Between Intake Tunnel and Spray Pond Feed Line

Nine (9) pipe sections, making up the entire crossover line between the intake tunnel and spray pond feed line, had been dug up by GPU and staged on the ground near the SSGS Boiler Pad area. The pipes were steel with a 24" diameter and lengths of about 8 feet. Four spectra and four scale samples were collected from the pipes. Laboratory analysis of scale samples and *in situ* gamma spectroscopy results are in relative agreement considering the measurement and sampling points were not perfectly aligned. All results were well within the DCGL's.

Table 4.2 – Results: Cross-Over Line Between Intake Tunnel and Spray Pond Feed Line

Measurement #		In situ Gamma Spectroscopic Results (dpm/100 sq.cm) Cs-137	Co-60	(estimated pCi/g) Cs-137	Co-60	GPU Laboratory Sampling Result ID	(pCi/g) Cs-137	Co-60	Description	Note
100901 A	1	458	< 269	1.6	< 0.9	1517	1.8	< 0.15	24" to spray pond #3	samp 36" from meas pt
100901 B	1	< 499	< 302	< 1.8	< 1.1	1519	0.6	< 0.1	24" to spray pond #9	samp 12" from meas pt
100901 C	1	< 393	< 255	< 1.4	< 0.9	1518	2.7	< 0.16	24" to spray pond #2	samp 30" from meas pt
100901 D	1	< 416	< 247	< 1.5	< 0.9	NoSamp	---	---	24" to spray pond #1	---

4.3 SSGS Sump Cross-Over Lines

Two pipes were removed from the SSGS below-grade facility by GPU, and were staged for radioactive waste disposal in the Decommissioning Support Facility (DSF) building. These pipe sections were originally crossover lines between the SSGS facility sumps. Measurements and sampling were performed of these pipes as a test of the *in situ* methodology with known contaminated objects. Laboratory analysis of scale samples and *in situ* gamma spectroscopy results were in good agreement.

Table 4.3 – Results: SSGS Sump Crossover Lines

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
#		Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
100901 E	1	78152	< 2077	73.9	< 2.0	1521	74	0.3	3.75" Sump to sump cross-over	meas. made exterior to pipe
100901 F	1	5445	< 1874	6.4	< 2.2	NoSamp	---	---	3 "Sump to sump cross-over	meas. made exterior to pipe
100901 G	1	337[illegible]5	< 481	101.2	< 1.4	1521	74	0.3	same as "E" - cut in thirds	meas. made inside pipe

4.4 Small Garage – Drain Openings

One (1) drain/sump exists in each of the 4 bays of the small garage. The 15" diameter x 32" deep sumps are ceramic lined. One 6" diameter pipe drains each sump to a main header line that eventually ties in to the 42" diameter Shunt Line. One sediment sample and 2 or 3 *in situ* measurements were collected from each sump. Before measurements, most of the sediment was manually cleaned-out (approximately 1" remaining), except for Bay 2 in which measurements were performed before and after cleaning. Laboratory analysis of sediment samples and *in situ* gamma spectroscopy results were in good agreement. The *in situ* measurement MDA's for the sumps are relatively high because of the higher background due to naturally occurring radium and thorium in the ceramic sump material. However, all results and MDA's are within DCGL's.

Table 4.4 – Results: Small Garage – Drain Openings

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
#		Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
101001 A	1	< 1921	< 1270	< 2.1	< 1.4	1525	0.42	< 0.06	Drain Sump - Garage Bay 1	sediment removed before meas.
101001 A	2	< 664	< 421	< 2.3	< 1.5	NoSamp	---	---	Drain Pipe - Garage Bay 1	---
101001 B	1	< 2134	< 1209	< 3.8	< 2.1	1522	0.5	< 0.06	Drain Sump - Garage Bay 2	~12" sediment in place during meas.
101001 B	2	< 1994	< 1104	< 2.2	< 1.2	NoSamp	---	---	Drain Sump - Garage Bay 2	sediment removed before meas.
101001 B	3	< 695	< 422	< 2.4	< 1.5	NoSamp	---	---	Drain Pipe - Garage Bay 2	---
101001 C	1	< 2064	< 1162	< 2.3	< 1.3	1523	0.2	< 0.06	Drain Sump - Garage Bay 3	sediment removed before meas.
101001 C	2	< 678	< 412	< 2.4	< 1.5	NoSamp	---	---	Drain Pipe - Garage Bay 3	---
101001 C	1D	< 2051	< 1213	< 2.3	< 1.3	NoSamp	---	---	dup-Drain Pipe - Garage Bay 3	---
101001 D	1	< 2014	< 1122	< 2.2	< 1.2	1524	1.4	0.06	Drain Sump - Garage Bay 4	sediment removed before meas.
101001 D	2	< 670	< 391	< 2.4	< 1.4	NoSamp	---	---	Drain Pipe - Garage Bay 4	---

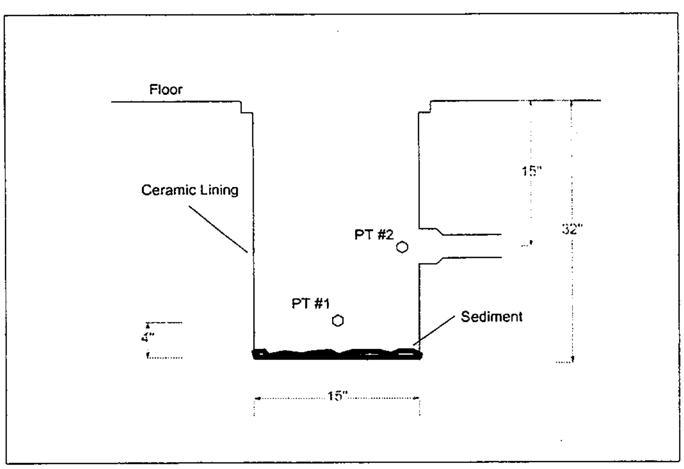


Figure 4.4 – Garage Drain Sectional View (Typical)

4.5 Yard Drain - Center Yard and 16" Line Behind Garage

The center yard drain near Grid Point AN133 was manually cleaned of most sediment (approximately 1" remaining). After cleaning, an *in situ* measurement was performed in the sump and then 3 additional measurements were performed in the attached 16" ceramic pipe. The same pipe was unearthed downstream, after it passed under or near the garage, just before it connects to the Shunt Line. Seven (7) additional measurements were performed there with the last measurement point actually protruding into the Shunt Line. A sample was collected of the sediment removed from the sump and a sample of the ceramic pipe wall was collected from the unearthed section because no scale was present there. Laboratory analysis of the samples and *in situ* gamma spectroscopy results were in good agreement. All results are well within the DCGL's.

Table 4.5 – Results: Yard Drain, Center and 16" Line Behind Garage

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
#		Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
101001 E	1	910	< 507	1.0	< 0.6	1526	1.1	< 0.03	Yard drain sump at AN133	sediment removed before meas.
101001 E	2	< 335	< 203	< 1.2	< 0.7	NoSamp	---	---	16" drain pipe from sump	---
101001 E	3	< 357	< 246	< 1.3	< 0.9	NoSamp	---	---	16" drain pipe from sump	---
101001 E	4	< 372	< 247	< 1.3	< 0.9	NoSamp	---	---	16" drain pipe from sump	---
102301A	1	< 443	< 250	< 1.6	< 0.9	1560	< 0.07	< 0.08	16" drain pipe from sump	sample of ceramic pipe wall
102301A	2	< 480	< 296	< 1.7	< 1.0	NoSamp	---	---	16" drain pipe from sump	---
102301A	3	< 477	< 297	< 1.7	< 1.0	NoSamp	---	---	16" drain pipe from sump	---
102301A	4	< 432	< 254	< 1.5	< 0.9	NoSamp	---	---	16" drain pipe from sump	---
102301A	5	< 330	< 201	< 1.2	< 0.7	NoSamp	---	---	16" drain pipe from sump	---
102301A	6	< 355	< 229	< 1.2	< 0.8	NoSamp	---	---	16" drain pipe from sump	---
102301A	7	< 559	< 325	< 2.0	< 1.1	NoSamp	---	---	12" protruding into shunt	---

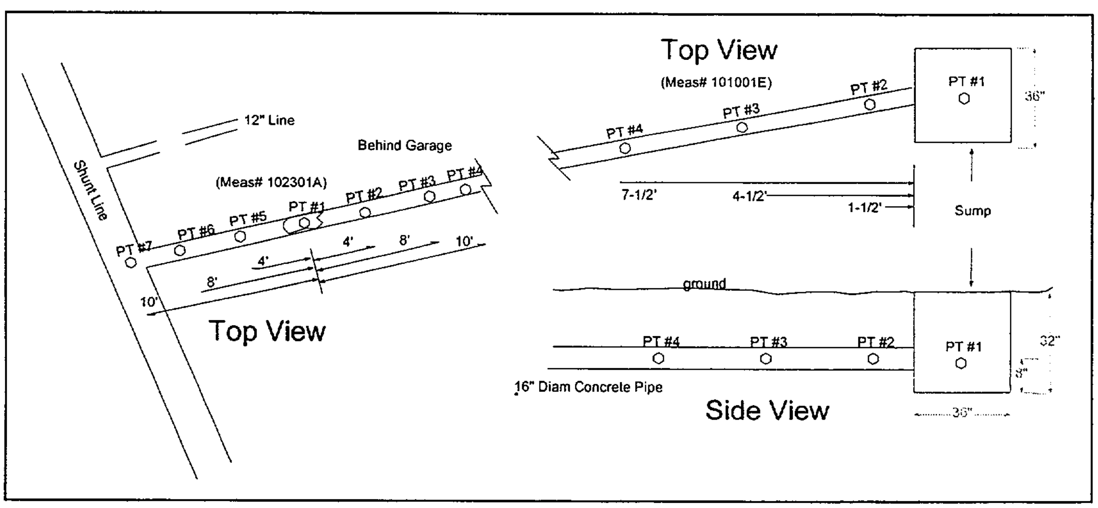


Figure 4.5 – Yard Drain, Center and 16" Line Behind Garage

4.6 Yard Drain - Near Warehouse

The yard drain near the Warehouse near Grid Point AO130 was manually cleaned of most of its sediment (approximately 1" remaining). After cleaning, an *in situ* measurement was performed in the sump and then 4 additional measurements were performed in the attached 12" corrugated steel pipe. A sample was collected of the sediment removed from the sump. Laboratory analysis of the sample and *in situ* gamma spectroscopy results was in good agreement. All results are well within the DCGL's.

Table 4.6 – Results: Yard Drain Near Warehouse

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
#		Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
101101A	1	< 1633	< 991	< 1.8	< 1.1	1527	0.7	< 0.07	Yard drain sump at AO130	sediment removed before meas.
101101A	2	< 372	< 241	< 1.3	< 0.8	NoSamp	---	---	12" drain pipe from sump	---
101101A	3	< 397	< 247	< 1.4	< 0.9	NoSamp	---	---	12" drain pipe from sump	---
101101A	4	< 375	< 229	< 1.3	< 0.8	NoSamp	---	---	12" drain pipe from sump	---
101101A	5	< 309	< 182	< 1.1	< 0.6	NoSamp	---	---	12" drain pipe from sump	---

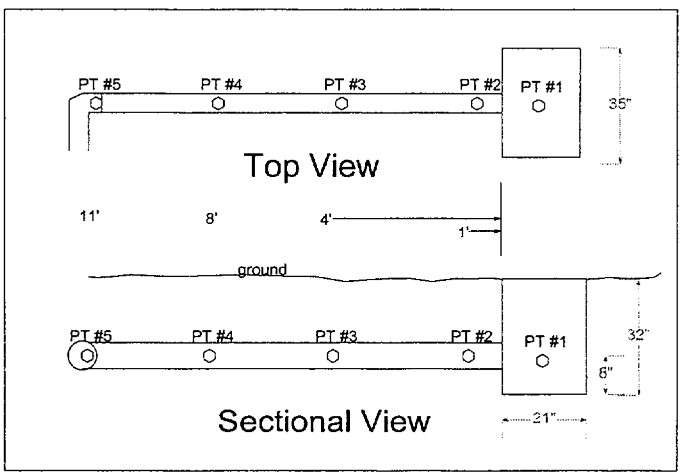


Figure 4.6 - Yard Drain Near Warehouse

4.7 18" Pipe in SSGS Area Footprint

The 18" diameter steel pipe in the SSGS connects the discharge tunnel to the Screen/Rake section of the Intake Tunnel. One scale sample and 18 *in situ* measurements were collected as well as 3 additional samples collected previous to this study. Laboratory analysis of the 4 scale samples and *in situ* gamma spectroscopy results were in general agreement, with the sampling results about 2 to 3 times greater than the *in situ* result. The differences are likely due to the reasons discussed in Sections 3.1 and 4.0. However, results are well within DCGL's.

Table 4.7 – Results: 18" Pipe in SSGS Area Footprint

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
	#	Cs-137	Co-60	Cs-137	Co-60	SX ID#	Cs-137	Co-60		
101101B	1	236	< 83	0.8	< 0.3	1534	0.66	0.1	18" pipe in SSGS	5' from tunnel, in valve
101101B	2	209	< 85	0.7	< 0.3	344	1.2	---	18" pipe in SSGS	3' from tunnel
101101B	3	< 264	< 147	< 0.9	< 0.5	NoSamp	---	---	18" pipe in SSGS	1' from tunnel
101101B	4	< 174	< 133	< 0.6	< 0.5	NoSamp	---	---	18" pipe in SSGS	8.5' from tunnel
101101B	5	< 206	< 129	< 0.7	< 0.5	NoSamp	---	---	18" pipe in SSGS	11' from tunnel
101101B	6	< 211	< 109	< 0.7	< 0.4	NoSamp	---	---	18" pipe in SSGS	13' from tunnel
101101B	7	< 210	< 151	< 0.7	< 0.5	NoSamp	---	---	18" pipe in SSGS	15' from tunnel
101101B	8	< 232	< 173	< 0.8	< 0.6	NoSamp	---	---	18" pipe in SSGS	17' from tunnel
101101B	9	< 244	< 180	< 0.9	< 0.6	NoSamp	---	---	18" pipe in SSGS	19' from tunnel
101101B	10	< 262	< 155	< 0.9	< 0.5	NoSamp	---	---	18" pipe in SSGS	21' from tunnel
101101B	11	< 238	< 154	< 0.8	< 0.5	NoSamp	---	---	18" pipe in SSGS	23' from tunnel
101101B	12	< 285	< 180	< 1.0	< 0.6	NoSamp	---	---	18" pipe in SSGS	25' from tunnel
101101B	13	< 258	< 192	< 0.9	< 0.7	NoSamp	---	---	18" pipe in SSGS	27' from tunnel
101101B	14	< 208	< 154	< 0.7	< 0.5	NoSamp	---	---	18" pipe in SSGS	29' from tunnel
101101B	15	< 271	< 127	< 1.0	< 0.4	NoSamp	---	---	18" pipe in SSGS	31' from tunnel
101101B	16	< 274	< 160	< 1.0	< 0.6	NoSamp	---	---	18" pipe in SSGS	33' from tunnel
101101B	17	375	< 200	1.3	< 0.7	NoSamp	---	---	18" pipe in SSGS	35' from tunnel
101101B	18	283	< 135	1.0	< 0.5	938	3.2	< 0.15	18" pipe in SSGS	37' from tunnel
NoMeas	---	---	---	---	---	939	4.24	< 0.1	18" pipe in SSGS	42' from tunnel
NoMeas	---	---	---	---	---	953	1.76	< 0.11	18" pipe in SSGS	60' from tunnel

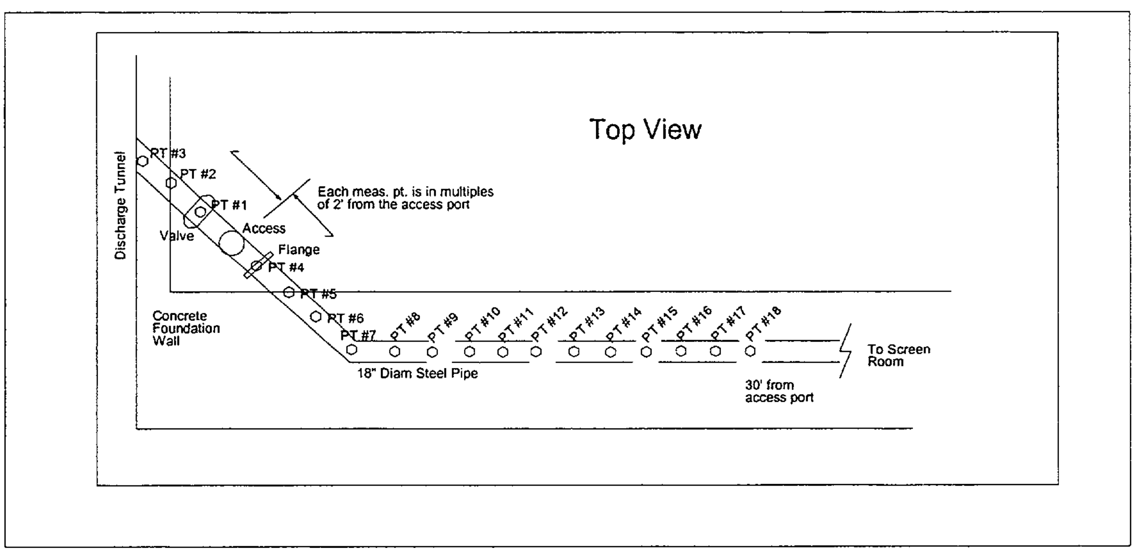


Figure 4.7 – 18" Pipe in SSGS Area Footprint

4.8 12" Drain Line into Shunt (outside fence)

The 12" diameter ceramic pipe outside the fence south of the garage was unearthed near Grid Point AL137. One ceramic sample and 12 *in situ* measurements were collected, 1 upstream from the entry point and 11 downstream towards the shunt line. The last measurement point was actually protruding into the shunt line. Laboratory analysis of the ceramic sample and *in situ* gamma spectroscopy results was in good agreement. No contamination was detected and thus all results were well within the DCGL's.

Table 4.8 - Results: 12" Drain Line into Shunt (outside fence)

Measurement		In situ Gamma Spectroscopic Results (dpm/100 sq.cm)		(estimated pCi/g)		GPU Laboratory Sampling Result	(pCi/g)		Description	Note
	#	Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
102201A	1	< 471	< 279	< 1.7	< 1.0	1558	< 0.1	< 0.1	12" pipe into shunt	sample of ceramic pipe wall
102201A	2	< 513	312	< 1.8	1.1	NoSamp	---	---	12" pipe into shunt	---
102201A	3	< 474	< 269	< 1.7	< 0.9	NoSamp	---	---	12" pipe into shunt	---
102201A	4	< 507	< 277	< 1.8	< 1.0	NoSamp	---	---	12" pipe into shunt	---
102201A	5	< 549	< 330	< 1.9	< 1.2	NoSamp	---	---	12" pipe into shunt	---
102201A	6	< 493	< 293	< 1.7	< 1.0	NoSamp	---	---	12" pipe into shunt	---
102201A	7	< 512	< 308	< 1.8	< 1.1	NoSamp	---	---	12" pipe into shunt	---
102201A	8	< 427	< 247	< 1.5	< 0.9	NoSamp	---	---	12" pipe into shunt	---
102201A	9	< 336	< 221	< 1.2	< 0.8	NoSamp	---	---	12" pipe into shunt	---
102201A	10	< 398	< 216	< 1.4	< 0.8	NoSamp	---	---	12" pipe into shunt	---
102201A	11	< 345	< 203	< 1.2	< 0.7	NoSamp	---	---	12" pipe into shunt	---
102201A	12	< 656	< 405	< 2.3	< 1.4	NoSamp	---	---	protruding into shunt	---
102201A	3D	< 488	< 299	< 1.7	< 1.1	NoSamp	---	---	dup-12" pipe into shunt	---
102201A	12D	< 642	< 404	< 2.3	< 1.4	NoSamp	---	---	dup-protruding into shunt	---

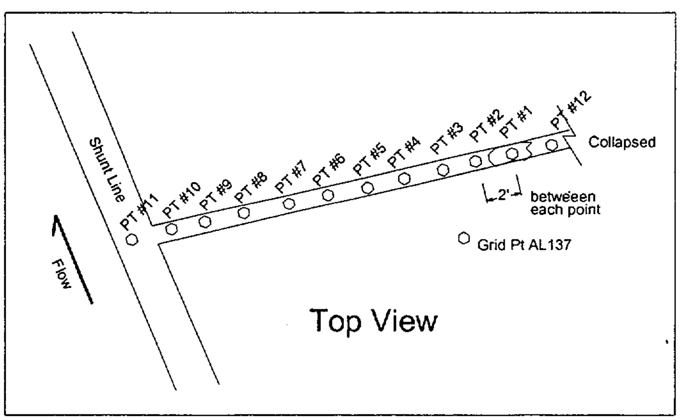


Figure 4.8 - 12" Drain Line into Shunt (outside fence)

4.9 Unknown 12" Drainage Line East of Small Garage

The 12" diameter ceramic pipe was unearthed behind the northern end of the garage. The origin of the pipe is unknown, but it comes from the direction of the boiler pad and probably drained a yard sump that is no longer present. One ceramic sample was collected and 8 *in situ* measurements were performed, 2 upstream from the entry point and 4 downstream towards the shunt line. The last measurement point was actually protruding into the shunt line. No detectable contamination was found, thus all results were well within DCGL's.

Table 4.9 – Results: Unknown 12" Drainage Line East of Small Garage

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
#		Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
102201B	1	< 446	< 237	< 1.6	< 0.8	1559	< 0.1	< 0.1	12" unknown line into shunt	sample of ceramic pipe wall
102201B	2	< 484	< 297	< 1.7	< 1.0	NoSamp	---	---	12" unknown line into shunt	---
102201B	3	< 515	< 317	< 1.8	< 1.1	NoSamp	---	---	12" unknown line into shunt	---
102201B	4	< 565	< 327	< 2.0	< 1.2	NoSamp	---	---	12" unknown line into shunt	---
102201B	5	< 550	< 347	< 1.9	< 1.2	NoSamp	---	---	12" unknown line into shunt	---
102201B	6	< 476	< 298	< 1.7	< 1.0	NoSamp	---	---	12" unknown line into shunt	---
102201B	7	< 360	< 236	< 1.3	< 0.8	NoSamp	---	---	12" unknown line into shunt	---
102201B	8	< 516	< 303	< 1.8	< 1.1	NoSamp	---	---	protruding into shunt	---
102201B	8D	< 523	< 279	< 1.8	< 1.0	NoSamp	---	---	dup-protruding into shunt	---

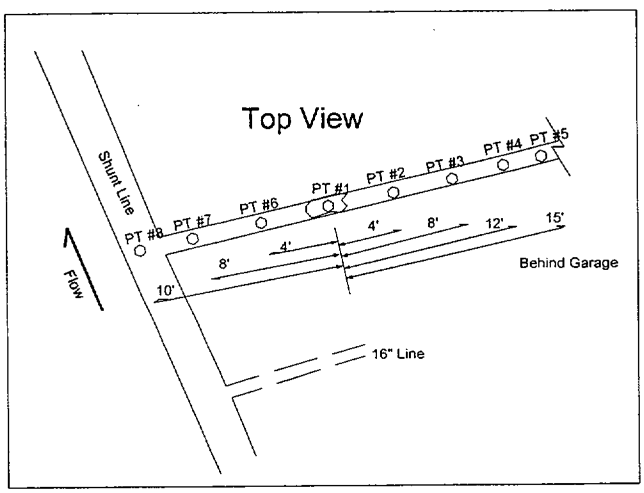


Figure 4.9 – Unknown 12" Drainage Line Behind the Small Garage

4.10 3 Pipes in NW SSGS Above Seal Chamber #3

The 3 steel pipes in the SSGS over seal chamber #3 originally emptied into the discharge tunnel. One scale sample from each of the 3 pipes was collected and 18 *in situ* measurements were performed. Laboratory analysis of the scale samples and *in situ* gamma spectroscopy results were in good agreement. While some of the results showed detectable cesium-137, all results are well within DCGL's.

Table 4.10 – Results: 3 Pipes in NW SSGS Above Seal Chamber #3

Measurement	#	In situ Gamma Spectroscopic Results (dpm/100 sq.cm) Cs-137	Co-60	(estimated pCi/g) Cs-137	Co-60	GPU Laboratory Sampling Result ID	(pCi/g) Cs-137	Co-60	Description	Note
102301B	1	< 243	< 155	< 0.9	< 0.5	1561	0.16	< 0.08	top 8" pipe SSGS	scale sample
102301B	2	< 241	< 142	< 0.8	< 0.5	NoSamp	---	---	top 8" pipe SSGS	---
102301B	3	< 379	< 236	< 1.3	< 0.8	NoSamp	---	---	top 8" pipe SSGS	---
102301B	4	< 471	< 292	< 1.7	< 1.0	NoSamp	---	---	top 8" pipe SSGS	---
102301B	5	< 384	< 251	< 1.4	< 0.9	NoSamp	---	---	top 8" pipe SSGS	---
102301B	6	< 399	< 283	< 1.4	< 1.0	NoSamp	---	---	top 8" pipe SSGS	---
102301B	7	< 424	< 254	< 1.5	< 0.9	NoSamp	---	---	top 8" pipe SSGS	---
102301B	8	1178	< 174	4.1	< 0.6	1562	5.6	< 0.07	middle 6" pipe SSGS	scale sample
102301B	9	1478	< 242	5.2	< 0.9	NoSamp	---	---	middle 6" pipe SSGS	---
102301B	10	1112	< 329	3.9	< 1.2	NoSamp	---	---	middle 6" pipe SSGS	---
102301B	10D	1182	< 231	4.2	< 0.8	NoSamp	---	---	dup-middle 6" pipe SSGS	---
102301B	11	518	< 238	1.8	< 0.8	NoSamp	---	---	middle 6" pipe SSGS	---
102301B	12	639	< 286	2.3	< 1.0	NoSamp	---	---	middle 6" pipe SSGS	---
102301B	13	520	< 340	1.8	< 1.2	1563	2.3	< 0.1	bottom 8" pipe SSGS	scale sample
102301B	14	638	< 143	2.2	< 0.5	NoSamp	---	---	bottom 8" pipe SSGS	---
102301B	15	520	< 243	1.8	< 0.9	NoSamp	---	---	bottom 8" pipe SSGS	---
102301B	16	471	< 296	1.7	< 1.0	NoSamp	---	---	bottom 8" pipe SSGS	---
102301B	17	518	< 285	1.8	< 1.0	NoSamp	---	---	bottom 8" pipe SSGS	---
102301B	18	< 390	< 274	< 1.4	< 1.0	NoSamp	---	---	bottom 8" pipe SSGS	---

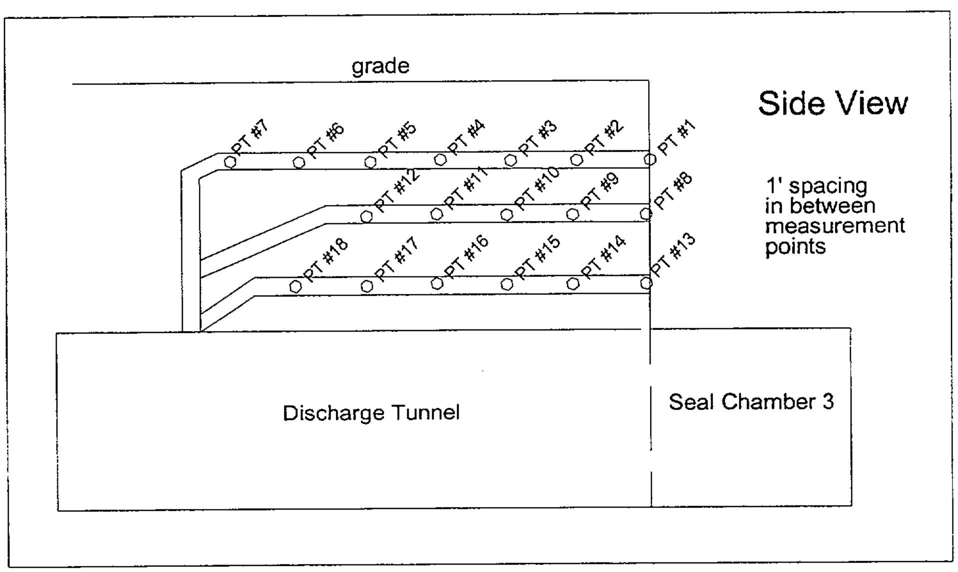


Figure 4.10 – 3 Pipes in NW SSGS Above Seal Chamber #3

4.11 Pipe in SW - SSGS Towards Intake Tunnel Screen Room

The 8" steel pipe in the southwest corner of the SSGS at the 803' level leads toward the screen room. One scale sample and 12 *in situ* measurements were collected. Laboratory analysis of the scale sample and *in situ* gamma spectroscopy results was in good agreement. While some of the results showed detectable cesium-137, all results are well within the DCGL's.

Table 4.11 – Results: Pipe in SW - SSGS Towards Intake Tunnel Screen Room

Measurement		In situ Gamma Spectroscopic Results				GPU Laboratory Sampling Result			Description	Note
		(dpm/100 sq.cm)		(estimated pCi/g)			(pCi/g)			
#		Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
102301C	1	< 255	< 207	< 0.9	< 0.7	1580	0.27	< 0.06	8" SW SSGS 803	scale sample
102301C	2	< 289	< 185	< 1.0	< 0.7	1581	0.25	0.036	8" SW SSGS 803	loose sediment & scale
102301C	3	336	< 172	1.2	< 0.6	NoSamp	---	---	8" SW SSGS 803	---
102301C	4	344	< 192	1.2	< 0.7	NoSamp	---	---	8" SW SSGS 803	---
102301C	5	394	< 227	1.4	< 0.8	NoSamp	---	---	8" SW SSGS 803	---
102301C	6	703	< 231	2.5	< 0.8	NoSamp	---	---	8" SW SSGS 803	---
102301C	6d	819	< 207	2.9	< 0.7	NoSamp	---	---	dup - 8" SW SSGS 803	---
102301C	7	659	< 207	2.3	< 0.7	NoSamp	---	---	8" SW SSGS 803	---
102301C	8	646	< 218	2.3	< 0.8	NoSamp	---	---	8" SW SSGS 803	---
102301C	9	652	< 191	2.3	< 0.7	NoSamp	---	---	8" SW SSGS 803	---
102301C	9d	667	< 201	2.3	< 0.7	NoSamp	---	---	dup - 8" SW SSGS 803	---
102301C	10	581	< 196	2.0	< 0.7	NoSamp	---	---	8" SW SSGS 803	---
102301C	11	< 310	< 205	< 1.1	< 0.7	NoSamp	---	---	8" SW SSGS 803	---
102301C	12	< 307	< 193	< 1.1	< 0.7	NoSamp	---	---	8" SW SSGS 803	---

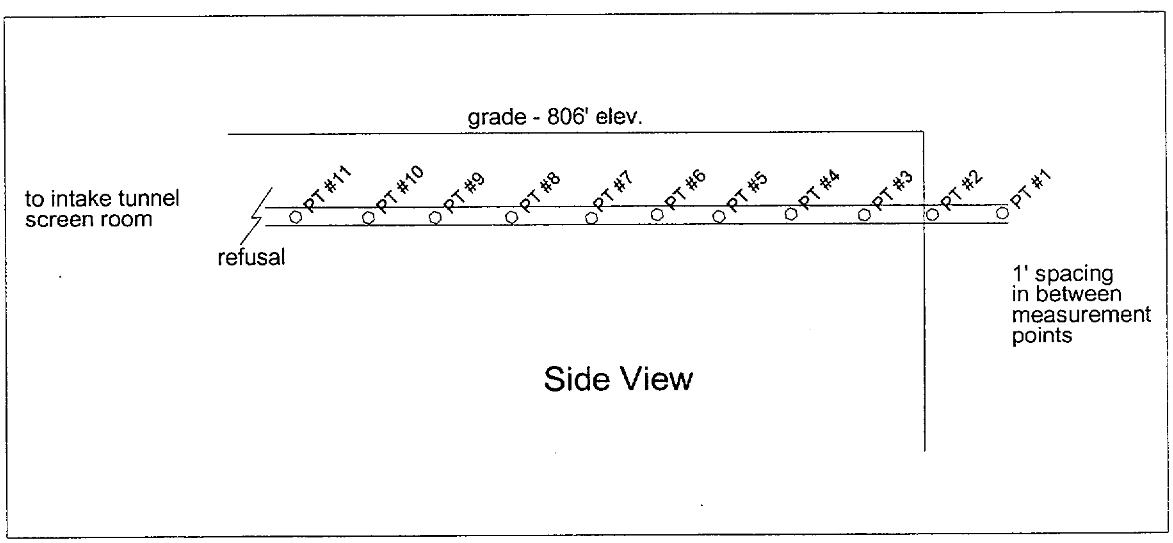


Figure 4.11 – Pipe in SW - SSGS Towards Intake Tunnel Screen Room

4.12 Drain Line from Warehouse to Shunt

The 18" ceramic pipe leads from the Warehouse to the Shunt line. The pipe was accessed via two 6 to 12 foot deep manholes. One sediment sample and 12 *in situ* measurements were collected. Laboratory analysis of the sample and *in situ* gamma spectroscopy results was in good agreement. All results are well within the DCGL's.

Table 4.12 – Results: Drain Line from Warehouse to Shunt

Measurement		In situ Gamma Spectroscopic Results (dpm/100 sq.cm)		(estimated pCi/g)		GPU Laboratory Sampling Result	(pCi/g)		Description	Note
	#	Cs-137	Co-60	Cs-137	Co-60	ID	Cs-137	Co-60		
102401A	1	< 309	< 205	< 1.1	< 0.7	1582	0.11	< 0.04	Warehouse to Shunt AK131	sediment from access hole
102401A	2	< 334	< 204	< 1.2	< 0.7	NoSamp	---	---	Warehouse to Shunt AK131	---
102401A	3	< 325	< 228	< 1.1	< 0.8	NoSamp	---	---	Warehouse to Shunt AK131	---
102401A	4	< 316	< 222	< 1.1	< 0.8	NoSamp	---	---	Warehouse to Shunt AK131	---
102401A	5	< 336	< 224	< 1.2	< 0.8	NoSamp	---	---	Warehouse to Shunt AK131	---
102401A	6	< 363	< 222	< 1.3	< 0.8	NoSamp	---	---	Warehouse to Shunt AK131	---
102401A	7	< 346	< 214	< 1.2	< 0.8	NoSamp	---	---	Warehouse to Shunt AK131	---
102401B	1	< 503	< 294	< 1.8	< 1.0	NoSamp	---	---	Warehouse to Shunt AG131	---
102401B	2	< 516	< 305	< 1.8	< 1.1	NoSamp	---	---	Warehouse to Shunt AG131	---
102401B	3	< 522	< 358	< 1.8	< 1.3	NoSamp	---	---	Warehouse to Shunt AG131	---
102401B	4	< 510	< 296	< 1.8	< 1.0	NoSamp	---	---	Warehouse to Shunt AG131	---
102401B	5	< 497	< 311	< 1.8	< 1.1	NoSamp	---	---	Warehouse to Shunt AG131	---

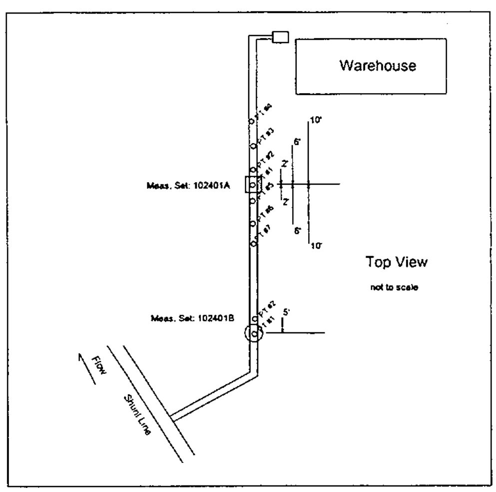


Figure 4.12 – Drain Linė from Warehouse to Shunt

4.13 Shunt Line and Yard Drain System Tie-ins

The 42" diameter Shunt Line was accessed at 6 points: the intake, at a manhole, a 12" line connection, a 16" line connection, another 12" line connection, and the outfall. Readings from the two 12" lines and the 16" line connection were displayed previously in Sections 4.5, 4.8, and 4.9, and are listed again here. Three (3) sediment samples were collected and 9 *in situ* measurements were performed. Laboratory analysis of the samples and *in situ* gamma spectroscopy results were in good agreement. All results are well within the DCGL's.

The model ("L") used for this pipe assumed ½" of water overlying the sediment layer (assumed to be 1" thick) resting on the bottom of the pipe. This is a reasonable model for the tie-in locations. However, at the intake and spillway (outfall) locations, observations indicated that a 2 to 6" deep layer of water actually occurred. Such a clean water over-layer would render low levels of radionuclides near the DCGL's in the sediment essentially non-detectable. Thus, the first four results in Table 4.13 below are underestimates of the MDA's. Therefore, the reader should rely on the sampling result for these locations.

The Shunt Line has a relatively high flow of clean stream water continually flowing through it. Thus, accumulation of radionuclides in it is unlikely. The sampling and *in situ* results herein confirm this conclusion. However, if further study of the line is required, future measurements should be performed during a dry season and/or with the inflow diverted so as to perform *in situ* measurements without an overlaying layer of water.

Table 4.13 – Results: Shunt Line and Yard Drain System Tie-ins

Measurement #		In situ Gamma Spectroscopic Results (dpm/100 sq.cm) Cs-137	Co-60	(estimated pCi/g) Cs-137	Co-60	GPU Laboratory Sampling Result ID	(pCi/g) Cs-137	Co-60	Description	Note
102501B	1	< 412*	< 279*	< 1.4*	< 1.0*	1589	0.04	< 0.12	Shunt intake at AE 131	sediment sample
102501B	1D	< 409*	< 303*	< 1.4*	< 1.1*	"	"	"	dup - Shunt intake at AE 131	"
102501C	1	< 418*	< 300*	< 1.5*	< 1.1*	1587	0.34	< 0.09	Shunt outfall at AX 145	sediment sample
102501C	2	< 409*	< 301*	< 1.4*	< 1.1*	1588	0.27	< 0.09	Shunt outfall at AX 145	sediment sample
102501A	1	< 694	< 430	< 2.4	< 1.5	NoSamp	---	---	Shunt at manhole at AE133	---
102501A	2	< 661	< 390	< 2.3	< 1.4	NoSamp	---	---	Shunt at manhole at AE133	---
102501A	3	< 617	< 399	< 2.2	< 1.4	NoSamp	---	---	Shunt at manhole at AE133	---
102201A	12	< 656	< 405	< 2.3	< 1.4	NoSamp	---	---	12" protruding into shunt	---
102201A	12D	< 642	< 404	< 2.3	< 1.4	NoSamp	---	---	dup - 12" protruding into shunt	---
102201B	8	< 516	< 303	< 1.8	< 1.1	NoSamp	---	---	12" unk.protruding into shunt	---
102201B	8D	< 523	< 279	< 1.8	< 1.0	NoSamp	---	---	dup -12" unk.protruding into shunt	---
102301A	7	< 559	< 325	< 2.0	< 1.1	NoSamp	---	---	16" protruding into shunt	---

* Overlaying water layer present not included in calculations, see discussion above.

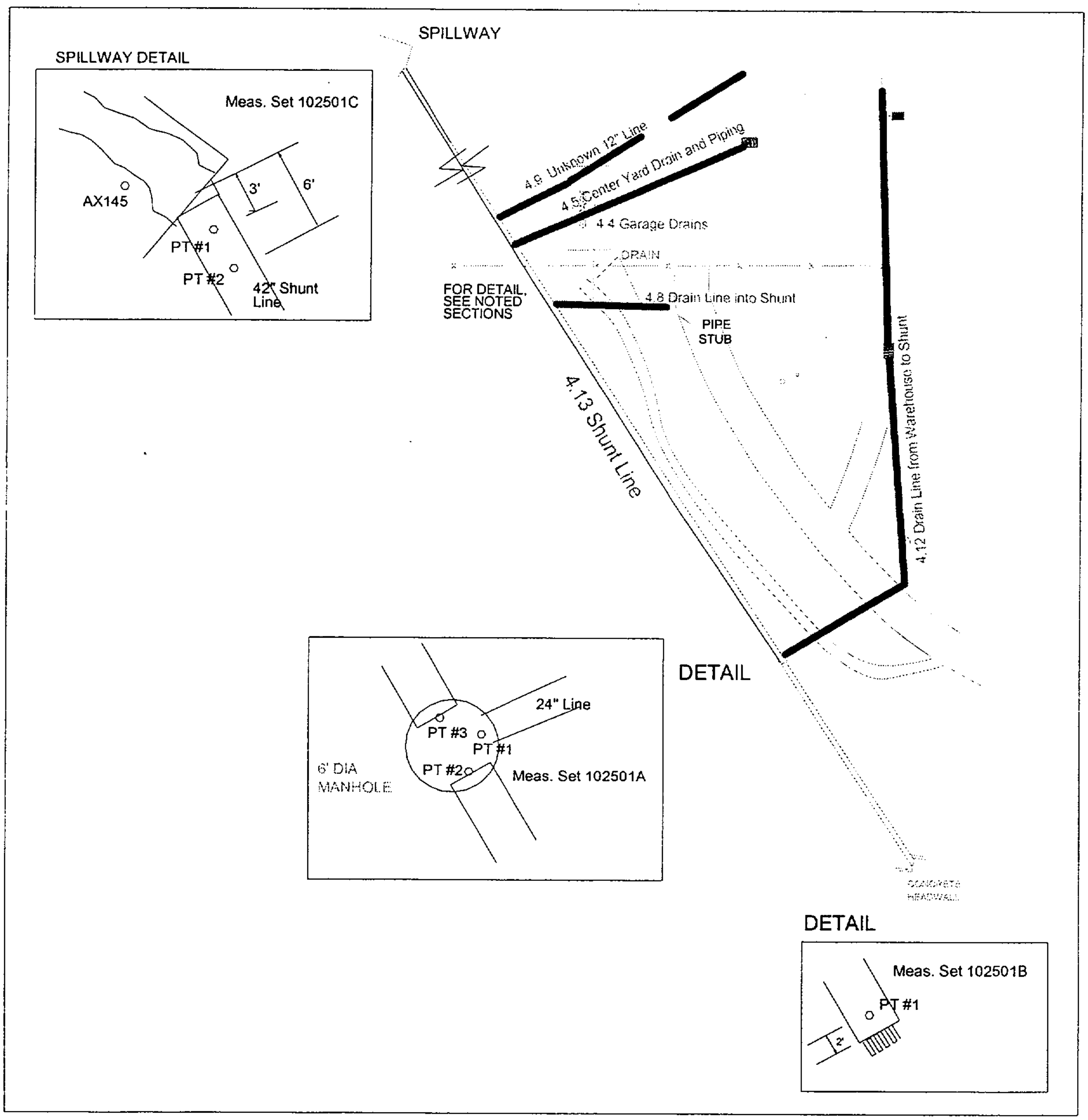


Figure 4.13 – Shunt Line and Yard Drain System Tie-ins

4.14 Summary of Embedded Pipe Systems Measured

The fraction of total pipe area surveyed was estimated for comparison to MARSSIM class 2 and 3 coverage recommendations. The fraction of total pipe area surveyed is proportional to the fraction of pipe length surveyed. The length of pipe surveyed per measurement point was conservatively estimated during detector calibration, i.e., the length of pipe easily visible to the detector was 2 pipe-diameters (> 90% spatial response). For example, for a 7.5 inch diameter pipe, each measurement viewed at least a 15-inch length of pipe. These pipe lengths surveyed were summed and entered into Table 4.14. The total length of pipe in a system was estimated from the site drawing.

Table 4.14 – Summary of Embedded Pipe Systems Measured

Report Section	Drain Sub-System	Typical Pipe Diameter (in.)	Length Measured (m)	Total Length* (m)	Fraction of Length Surveyed	> 50% of DCGL Detected ?
4.1	Boiler Pad Piping (partially removed)	3.75-9.5	3.1	14.2 (available) 338 (in ground)	0.22	no
4.2	Cross-Over Line Between Intake Tunnel to Spray Pond (removed)	24	4.9	~20	0.25	no
4.3	SSGS Sump Cross-Over Lines (removed – staged for disposal)	3.75	N/A - disposal	N/A - disposal	N/A - disposal	yes
4.4	Small Garage – Drain Openings	15"sump + 6" line + ~12"header	2.5	23	0.11	no
4.5	Yard Drain - Center and 16" Line Behind Garage	16	9	46	0.20	no
4.6 & 4.12	Yard Drain - Near Warehouse, Drain Line from Warehouse to Shunt	12 18	16	113	0.14	no
4.7	18" Pipe in SSGS	18	16.6	19	0.87	no
4.8	12" Drain Line into Shunt (outside fence)	12	7	27	0.26	no
4.9	Unknown 12" Drainage Line Behind the Small Garage	12	8	50 (est.)	0.16	no
4.10	3 Pipes in NW SSGS Above Seal Chamber 3	5.75-7.5	4.9	7.4	0.66	no
4.11	Pipe in SW SSGS Towards Screen Room	7.5	3.4	5 (est.)	0.68	no
4.13	Shunt Line and Yard Drain System Tie-ins	42	16	~260	.06	no

* Estimated Lengths

5.0 CONCLUSION

A survey of selected embedded and unearthed piping sections at the Saxton Nuclear Experimental Corporation (SNEC) Facility was performed using *in situ* gamma spectroscopy and sampling of pipe scale and sump sediment with subsequent laboratory analysis. The results show that radioactivity levels in these embedded systems are within site release limits (DCGL's), even using conservative assumptions regarding calculation of *in situ* radionuclide concentrations and application of the DCGL's to piping. It is anticipated that this piping will remain in place after license termination. Of the unearthed systems measured, one (SSGS sump crossover) showed levels exceeding a DCGL. These pipes had already been staged for eventual radioactive waste disposal.

REFERENCES

1. "Embedded Pipe Dose Calculation Method", EPRI 1000951, Final Report, Nov. 2000.

2. ANSI N42.12 - "Calibration and Usage of Sodium Iodide Detector Systems", American National Standards Institute, 1980, 1985.

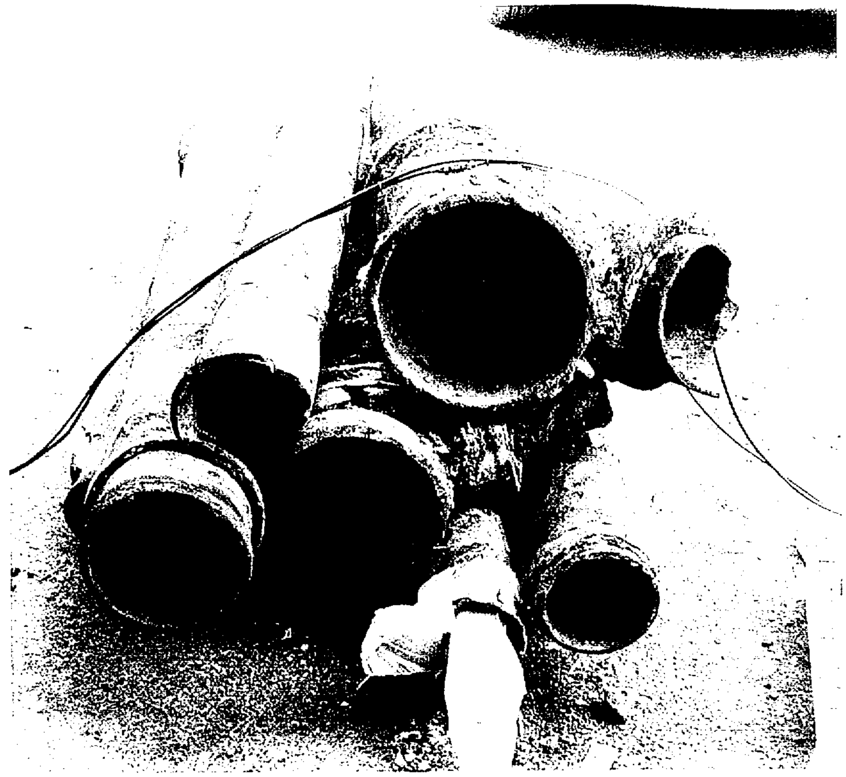
3. Saxton Nuclear, Survey Methodology to Support SNEC License Termination, E900-IMP-4520.04, Rev 0.

4. Saxton Nuclear, Operation of the Portable Gamma Spectroscopy System, E900-OPS-4524.43, Rev 0.

5. "Remediation of Embedded Piping: Trojan Nuclear Plant Decommissioning Experience", EPRI 1000908, Oct. 2000.

6. MicroShield Radiation Shielding Computer Code, Version 5.05, Grove Engineering, Rockville, MD.

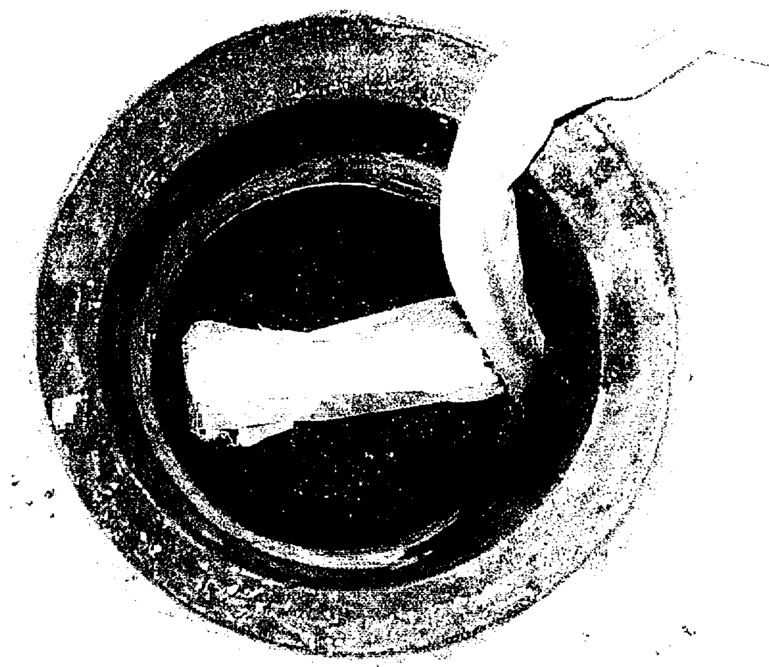
Appendix A – Photographs of Areas Surveyed



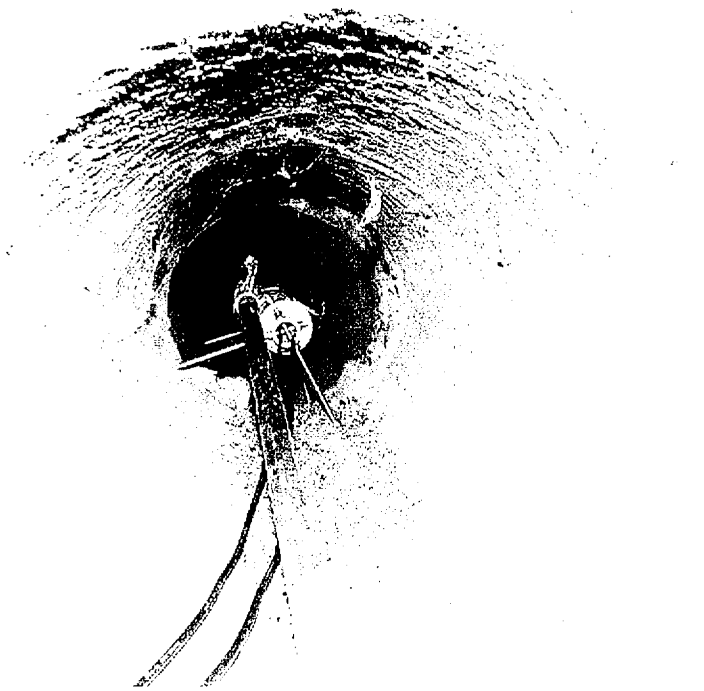
Photograph 4.1 – Boiler Pad Piping (Excavated Portion)

Photograph 4.2a – Cross-Over Line Between Intake Tunnel to Spray Pond

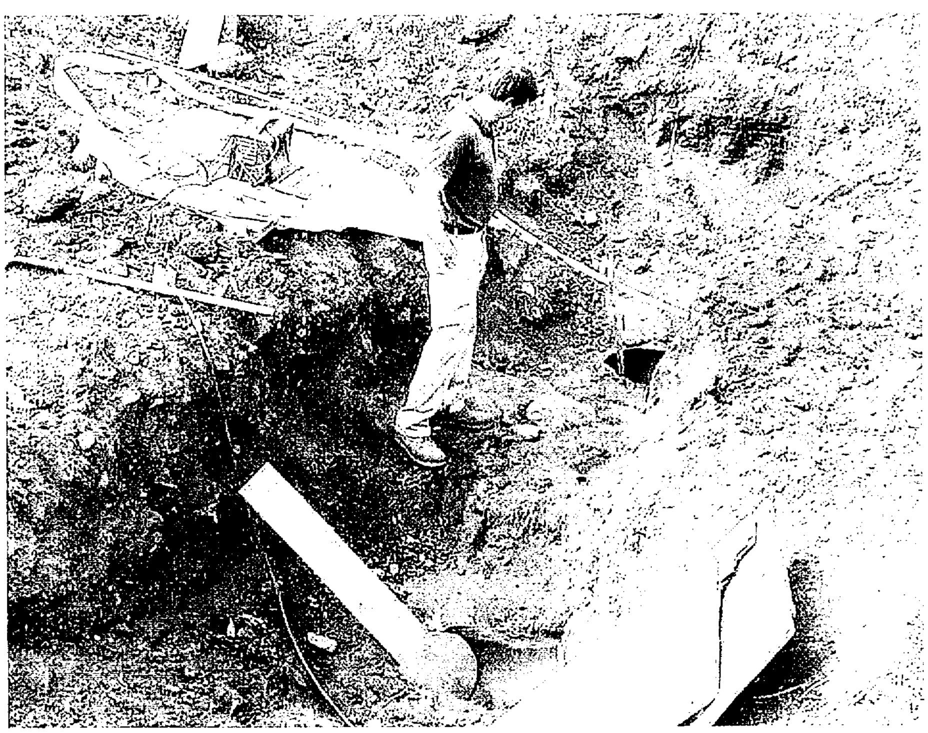
Photograph 4.2b – Cross-Over Line Between Intake Tunnel to Spray Pond



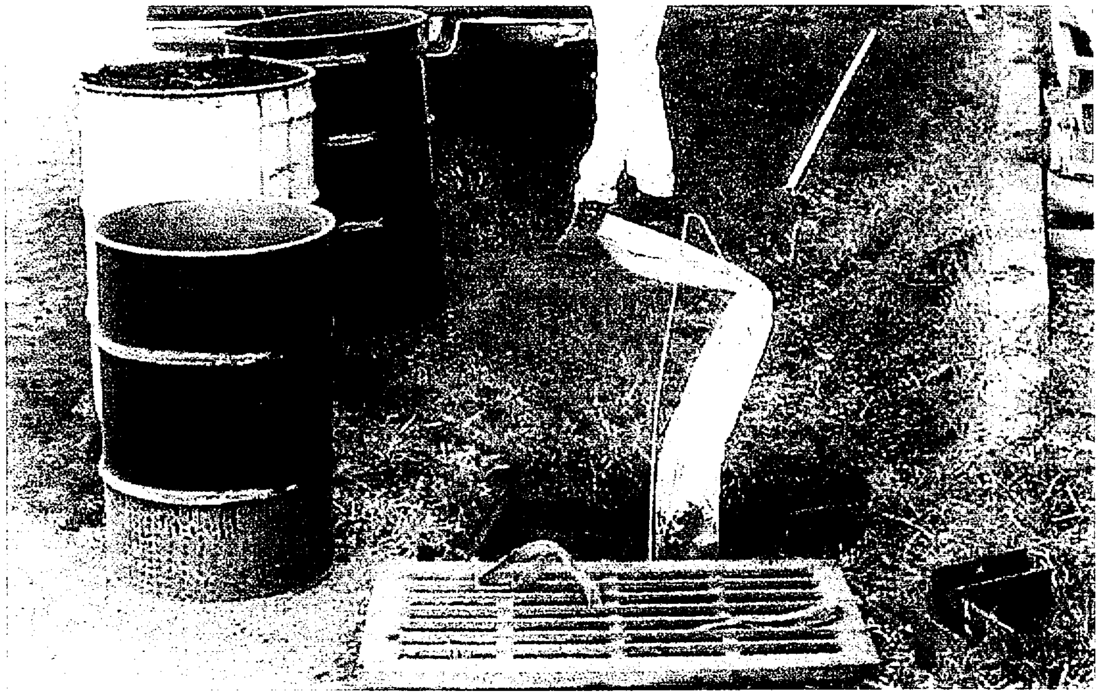
Photograph 4.4a – Small Garage – Drain Openings



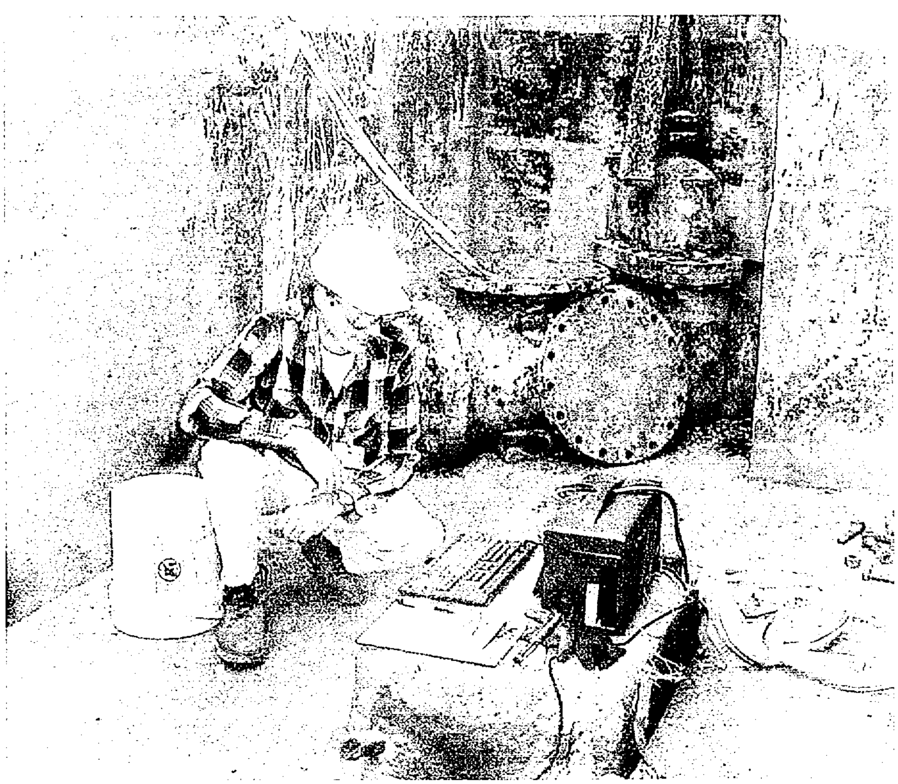
Photograph 4.5a – Center Yard Drain, Pipe Leading Away From Sump



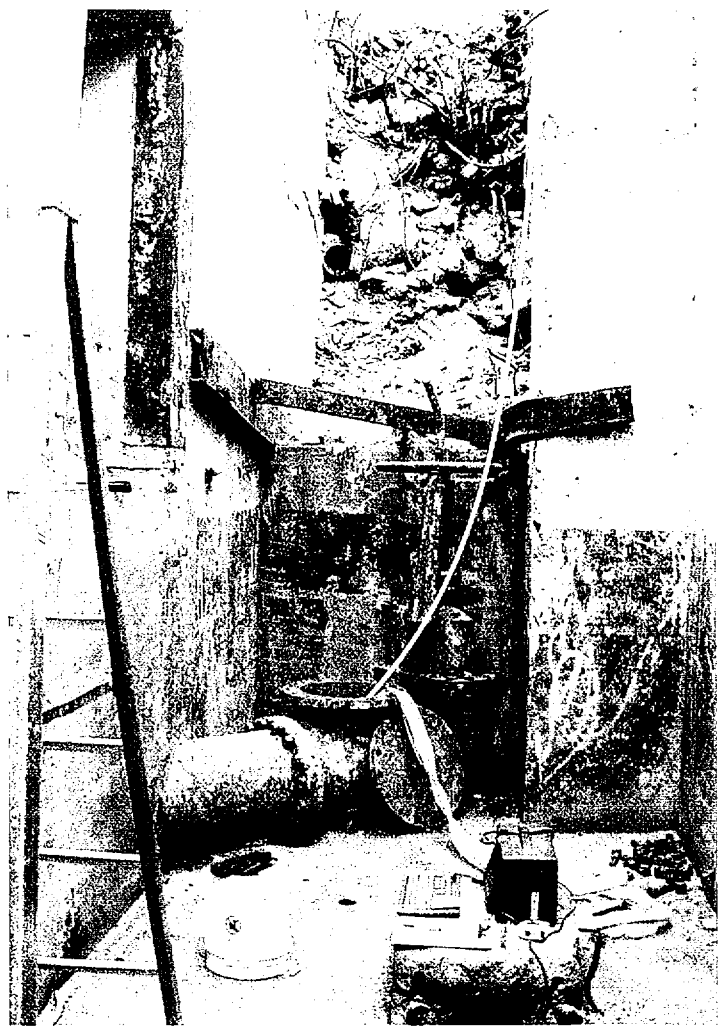
Photograph 4.5b – Center Yard Drain Pipe, Excavated Behind Garage (foreground)



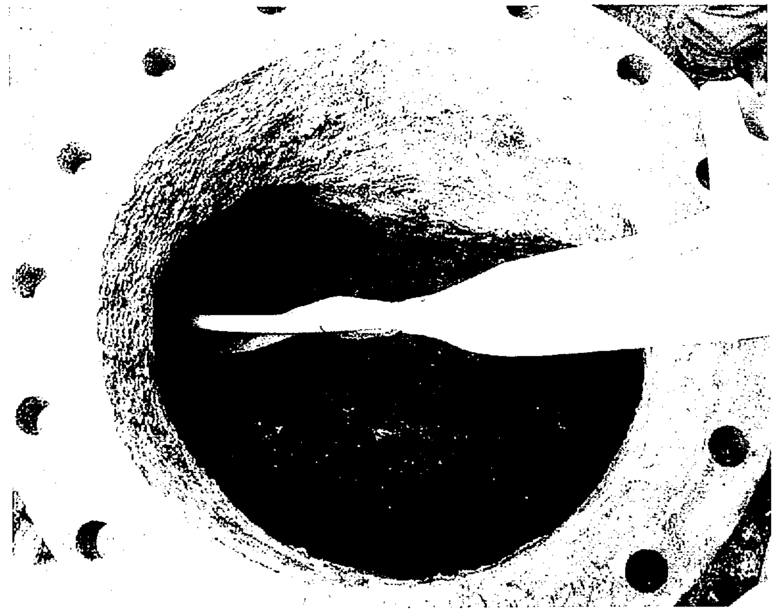
Photograph 4.6 – Yard Drain Near Warehouse



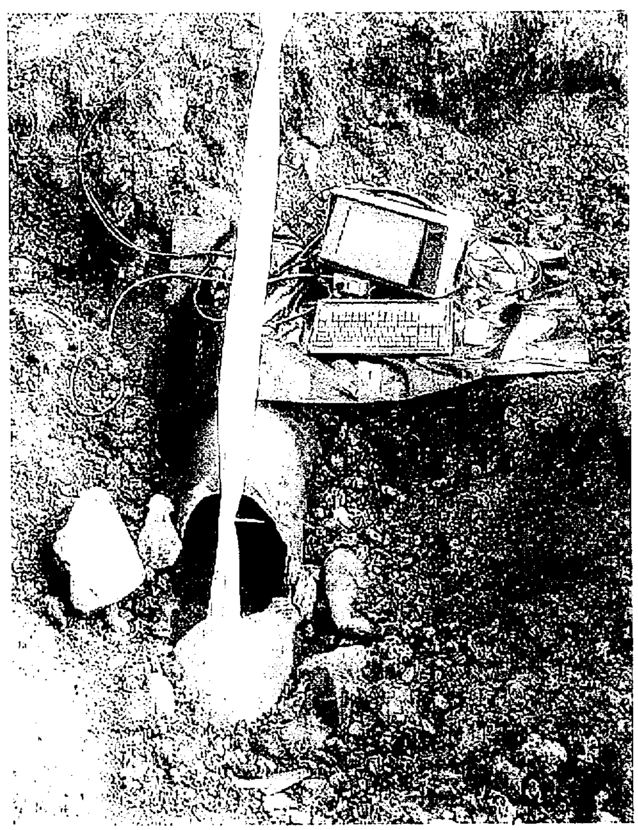
Photograph 4.7a – 18" Pipe in SSGS (upstream measurement)



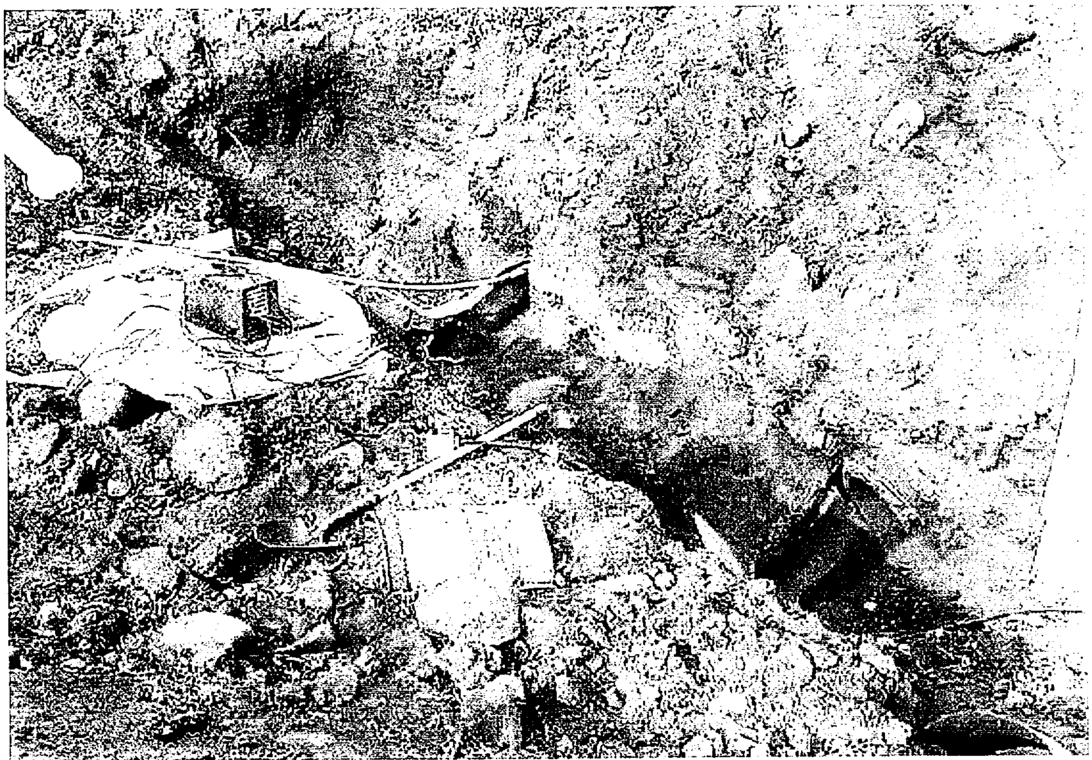
Photograph 4.7b – 18" Pipe in SSGS (downstream measurement)



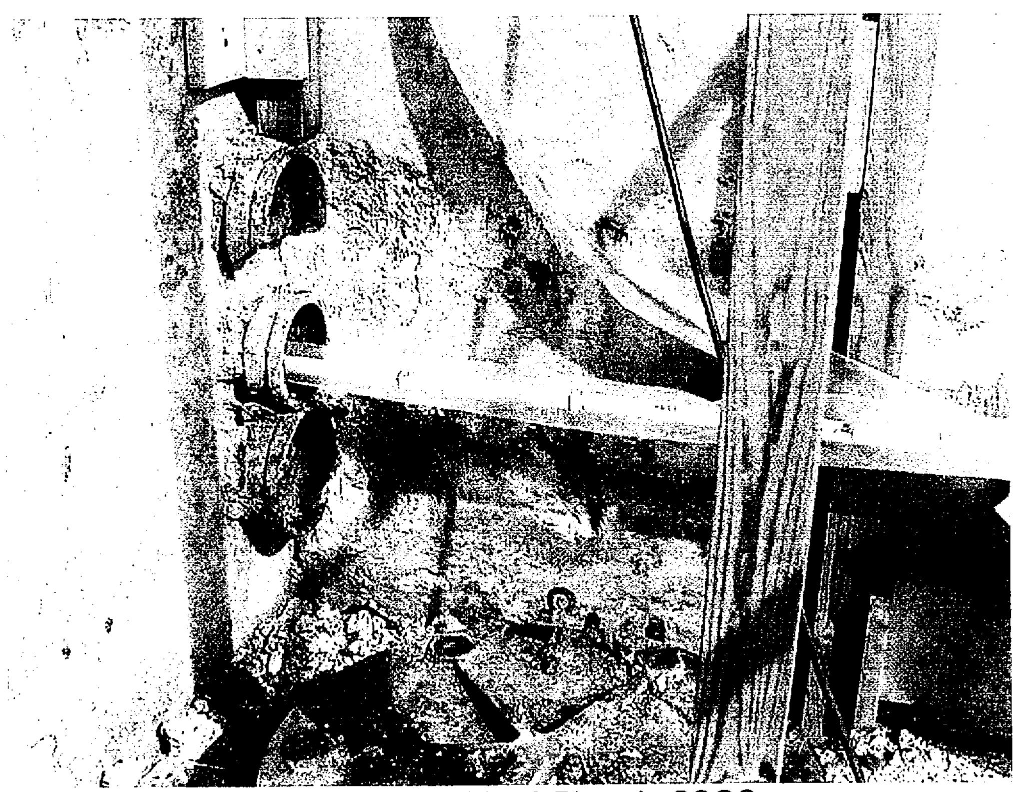
Photograph 4.7c – 18" Pipe in SSGS, Access Port



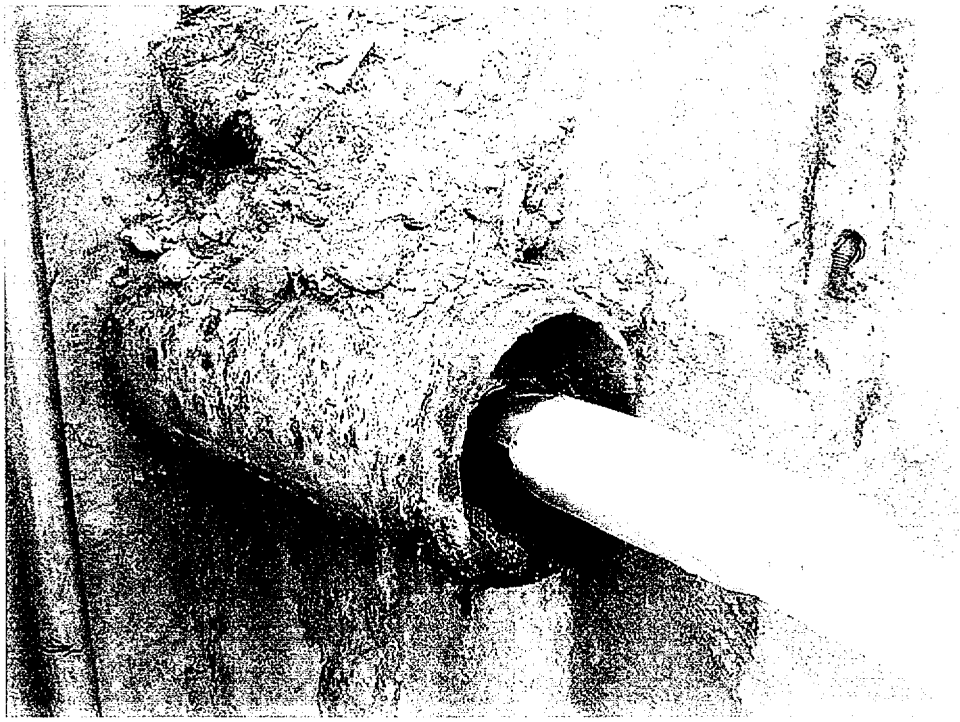
Photograph 4.8 – 12" Drain Line Outside Fence Near Garage



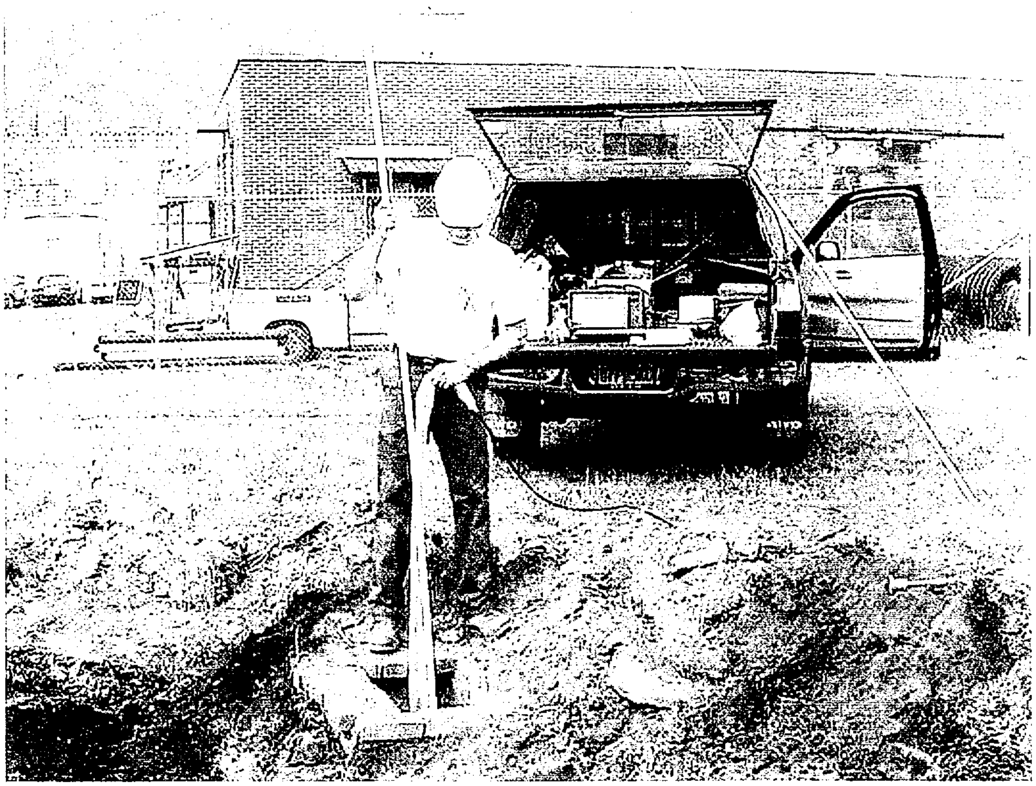
Photograph 4.9 – Unknown 12" Drain Line Behind Garage



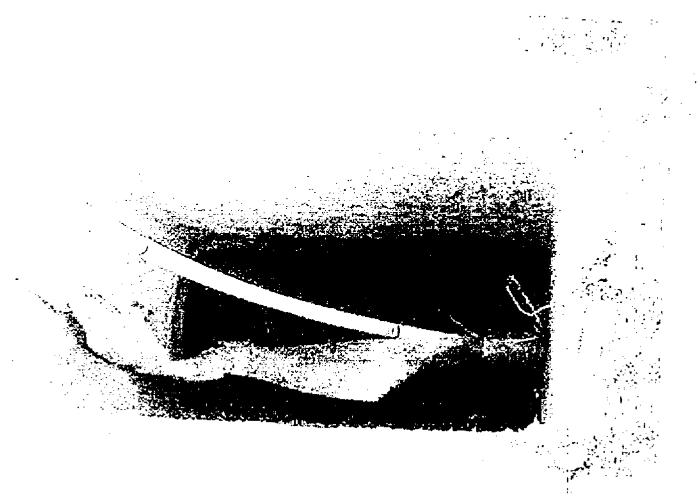
Photograph 4.10 – 3 Pipes in SSGS



Photograph 4.11 – 8" Pipe in SW SSGS Towards Screen Room



Photograph 4.12a – Drain Line From Warehouse to Shunt

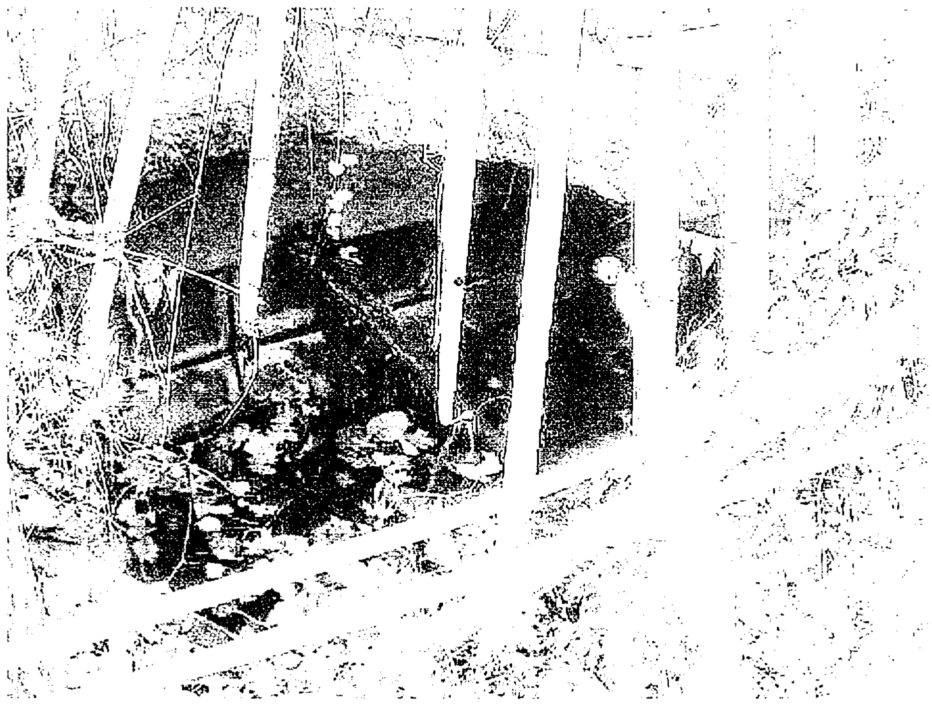


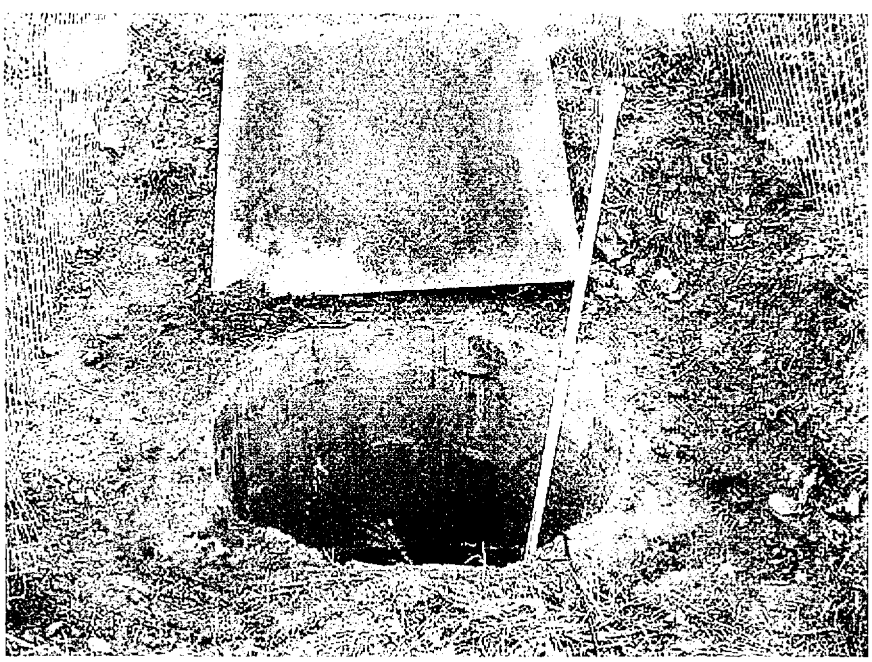
Photograph 4.12b – Drain Line From Warehouse to Shunt

Photograph 4.12c – Drain Line From Warehouse to Shunt

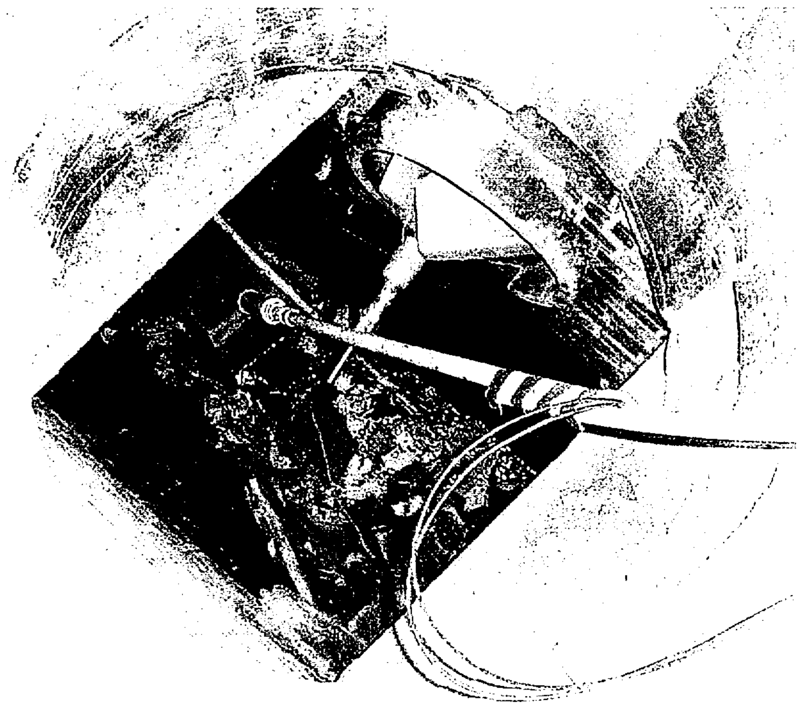
Photograph 4.12d – Drain Line From Warehouse to Shunt

Photograph 4.13a – Shunt Line, Inlet

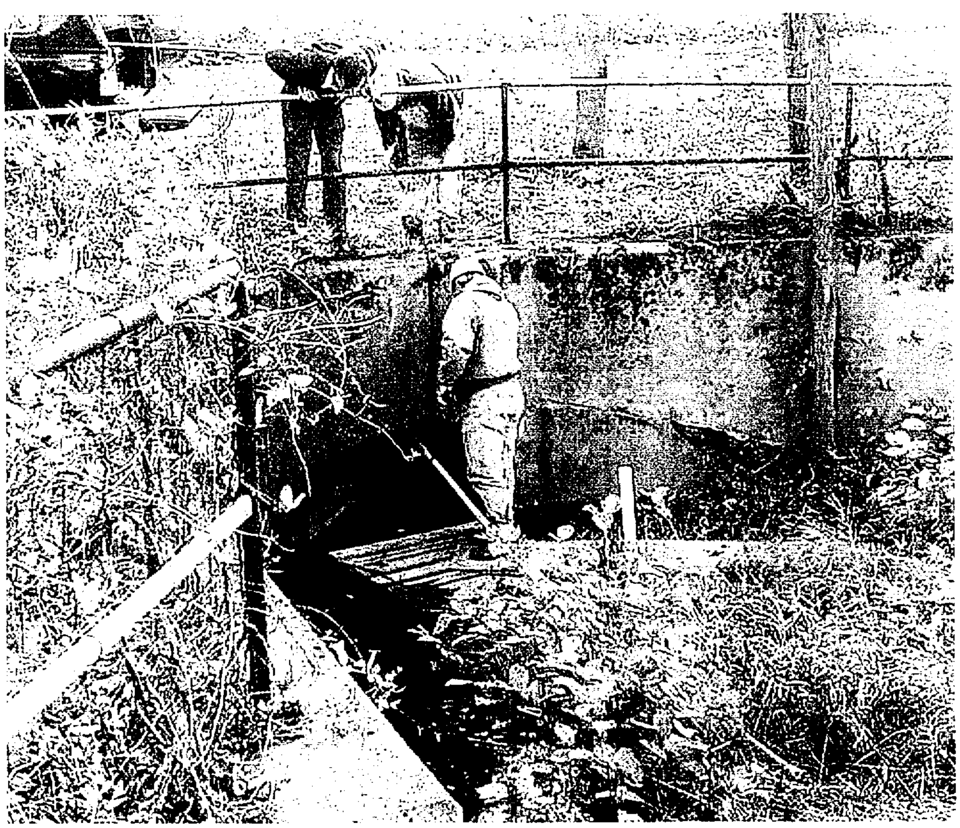

Photograph 4.13b – Shunt Line – Inlet



Photograph 4.13c – Shunt Line, 6' hole access



Photograph 4.13d – Shunt Line, 6' Hole Access, Showing Tie-in From Warehouse Line



Photograph 4.13e – Shunt Line, Spillway

Appendix B - SNEC Embedded Piping Survey Results

Pipe	Spec #	Geom. Model	Pipe or Sump Surface Activity (dpm/100 sq.cm) Cs-137 Activity	Cs-137 "+-2s"	Cs-137 MDA	Co-60 Activity	Co-60 "+-2s"	Co-60 MDA	Est.Parameters Sediment/Scale Density (g/cc)	Thick. (cm)	Concentration in Sediment or Scale (pCi/g) Cs-137 Conc.	Cs-137 "+-2s"	Cs-137 MDA	Co-60 Conc.	Co-60 "+-2s"	Co-60 MDA	GPU Laboratory Sampling Result (pCi/g) Cs-137	Co-60	Description
100801 A	1	C	-22	207	377	-12	163	244	2	0.64	-0.1	0.7	1.3	0.0	0.6	0.9	0.12	<0.09	6" - "South Boiler Pad"
100801 B	1	C	132	215	359	9	149	226	2	0.64	0.5	0.8	1.3	0.0	0.5	0.8	<0.09	<0.09	6" - "SSGS 806 East End"
100801 C	1	A	120	208	355	41	154	227	2	0.64	0.4	0.7	1.2	0.1	0.5	0.8	0.07	<0.09	8" - "Center"
100801 D	1	E	117	208	356	157	175	241	2	0.64	0.4	0.7	1.3	0.6	0.6	0.8	0.28	<0.09	10" - "Center"
100801 E	1	A	-69	179	306	47	140	209	2	0.64	-0.2	0.6	1.1	0.2	0.5	0.7	0.33	< 0.1	8"
100801 E	2	A	33	185	340	10	139	208	2	0.64	0.1	0.7	1.2	0.0	0.5	0.7	- - -	- - -	- - -
100801 F	1	M	-32	197	353	165	180	251	2	0.64	-0.1	0.7	1.2	0.6	0.6	0.9	< 1.1	< 1.2	4" - "South Boiler Pad"
100801 G	1	M	-31	197	353	217	185	248	2	0.64	-0.1	0.7	1.2	0.8	0.7	0.9	0.345	< 0.07	4" - "SSGS East End"
100901 A	1	H	458	309	431	101	189	269	2	0.64	1.6	1.1	1.5	0.4	0.7	0.9	1.8	< 0.15	24" to spray pond #3
100901 B	1	H	-102	290	499	-91	229	302	2	0.64	-0.4	1.0	1.8	-0.3	0.8	1.1	0.6	< 0.1	24" to spray pond #9
100901 C	1	H	188	243	393	163	186	255	2	0.64	0.7	0.9	1.4	0.6	0.7	0.9	2.7	< 0.16	24" to spray pond #2
100901 D	1	H	-155	258	416	-102	193	247	2	0.64	-0.5	0.9	1.5	-0.4	0.7	0.9	- - -	- - -	24" to spray pond #1
100901 E	1	N	78152	18975	8842	1082	1396	2077	1	4.763	73.9	17.9	8.4	1.0	1.3	2.0	74	0.3	3.75" Sump to sump cross-over
100901 F	1	P	5445	2929	3764	421	1203	1874	1	3.81	6.4	3.5	4.5	0.5	1.4	2.2	- - -	- - -	3 "Sump to sump cross-over
100901 G	1	M	33713	7873	3468	-55	314	481	1	1.5	101.2	23.6	10.4	-0.2	0.9	1.4	74	0.3	same as "E" - cut in thirds
101001 A	1	L	-664	1158	1921	755	970	1270	1.6	2.54	-0.7	1.3	2.1	0.8	1.1	1.4	0.42	< 0.06	Drain Sump - Garage Bay 1
101001 A	2	C	183	384	664	169	313	421	2	0.64	0.6	1.4	2.3	0.6	1.1	1.5	- - -	- - -	Drain Pipe - Garage Bay 1
101001 B	1	L	1633	1446	2134	940	970	1209	1	2.54	2.9	2.6	3.8	1.7	1.7	2.1	0.5	< 0.06	Drain Sump - Garage Bay 2
101001 B	2	L	635	1179	1994	51	769	1104	1.6	2.54	0.7	1.3	2.2	0.1	0.9	1.2	- - -	- - -	Drain Sump - Garage Bay 2
101001 B	3	C	151	403	695	311	334	422	2	0.64	0.5	1.4	2.4	1.1	1.2	1.5	- - -	- - -	Drain Pipe - Garage Bay 2
101001 C	1	L	1367	1365	2064	29	795	1162	1.6	2.54	1.5	1.5	2.3	0.0	0.9	1.3	0.2	< 0.06	Drain Sump - Garage Bay 3
101001 C	2	C	396	436	678	223	314	412	2	0.64	1.4	1.5	2.4	0.8	1.1	1.5	- - -	- - -	Drain Pipe - Garage Bay 3
101001 C	1D	L	1948	1462	2051	-157	856	1213	1.6	2.54	2.2	1.6	2.3	-0.2	0.9	1.3	- - -	- - -	dup-Drain Pipe - Garage Bay 3
101001 D	1	L	841	1251	2014	461	828	1122	1.6	2.54	0.9	1.4	2.2	0.5	0.9	1.2	1.4	0.06	Drain Sump - Garage Bay 4
101001 D	2	C	-41	371	670	-125	298	391	2	0.64	-0.1	1.3	2.4	-0.4	1.0	1.4	- - -	- - -	Drain Pipe - Garage Bay 4
101001 E	1	K	910	624	871	26	328	507	1.6	2.54	1.0	0.7	1.0	0.0	0.4	0.6	1.1	< 0.03	Yard drain sump at AN133
101001 E	2	F	173	213	335	-95	159	203	2	0.64	0.6	0.7	1.2	-0.3	0.6	0.7	- - -	- - -	16" drain pipe from sump
101001 E	3	F	-221	243	357	178	184	246	2	0.64	-0.8	0.9	1.3	0.6	0.6	0.9	- - -	- - -	16" drain pipe from sump
101001 E	4	F	-156	236	372	63	171	247	2	0.64	-0.5	0.8	1.3	0.2	0.6	0.9	- - -	- - -	16" drain pipe from sump
101101A	1	J	420	968	1633	227	681	991	1.6	2.54	0.5	1.1	1.8	0.3	0.8	1.1	0.7	< 0.07	Yard drain sump at AO130
101101A	2	F	65	213	372	135	177	241	2	0.64	0.2	0.7	1.3	0.5	0.6	0.8	- - -	- - -	12" drain pipe from sump
101101A	3	F	222	253	397	178	190	247	2	0.64	0.8	0.9	1.4	0.6	0.7	0.9	- - -	- - -	12" drain pipe from sump
101101A	4	F	327	262	375	112	166	229	2	0.64	1.2	0.9	1.3	0.4	0.6	0.8	- - -	- - -	12" drain pipe from sump
101101A	5	F	-10	168	309	-43	133	182	2	0.64	0.0	0.6	1.1	-0.1	0.5	0.6	- - -	- - -	12" drain pipe from sump
101101B	1	G	236	124	160	-39	62	83	2	0.64	0.8	0.4	0.6	-0.1	0.2	0.3	0.66	0.1	18" pipe in SSGS
101101B	2	G	209	134	183	-114	91	85	2	0.64	0.7	0.5	0.6	-0.4	0.3	0.3	1.2	NoAnal	18" pipe in SSGS
101101B	3	G	70	156	264	-72	118	147	2	0.64	0.2	0.6	0.9	-0.3	0.4	0.5	- - -	- - -	18" pipe in SSGS
101101B	4	G	131	109	174	97	84	133	2	0.64	0.5	0.4	0.6	0.3	0.3	0.5	- - -	- - -	18" pipe in SSGS
101101B	5	G	146	128	206	4	78	129	2	0.64	0.5	0.5	0.7	0.0	0.3	0.5	- - -	- - -	18" pipe in SSGS
101101B	6	G	73	119	211	-72	98	109	2	0.64	0.3	0.4	0.7	-0.3	0.3	0.4	- - -	- - -	18" pipe in SSGS
101101B	7	G	61	119	210	7	90	151	2	0.64	0.2	0.4	0.7	0.0	0.3	0.5	- - -	- - -	18" pipe in SSGS

Pipe	Spec #	Geom. Model	Pipe or Sump Surface Activity (dpm/100 sq.cm) Cs-137 Activity	Cs-137 "+-2s"	Cs-137 MDA	Co-60 Activity	Co-60 "+-2s"	Co-60 MDA	Est.Parameters Sediment/Scale Density (g/cc)	Thick. (cm)	Concentration in Sediment or Scale (pCi/g) Cs-137 Conc.	Cs-137 "+-2s"	Cs-137 MDA	Co-60 Conc.	Co-60 "+-2s"	Co-60 MDA	GPU Laboratory Sampling Result (pCi/g) Cs-137	Co-60	Description
101101B	8	G	-53	138	232	18	106	173	2	0.64	-0.2	0.5	0.8	0.1	0.4	0.6	---	---	18" pipe in SSGS
101101B	9	G	163	152	244	46	112	180	2	0.64	0.6	0.5	0.9	0.2	0.4	0.6	---	---	18" pipe in SSGS
101101B	10	G	131	163	262	-79	124	155	2	0.64	0.5	0.6	0.9	-0.3	0.4	0.5	---	---	18" pipe in SSGS
101101B	11	G	89	145	238	41	98	154	2	0.64	0.3	0.5	0.8	0.1	0.3	0.5	---	---	18" pipe in SSGS
101101B	12	G	131	178	285	-2	112	180	2	0.64	0.5	0.6	1.0	0.0	0.4	0.6	---	---	18" pipe in SSGS
101101B	13	G	50	144	258	146	124	192	2	0.64	0.2	0.5	0.9	0.5	0.4	0.7	---	---	18" pipe in SSGS
101101B	14	G	111	130	208	131	95	154	2	0.64	0.4	0.5	0.7	0.5	0.3	0.5	---	---	18" pipe in SSGS
101101B	15	G	184	174	271	-93	117	127	2	0.64	0.6	0.6	1.0	-0.3	0.4	0.4	---	---	18" pipe in SSGS
101101B	16	G	233	174	274	6	96	160	2	0.64	0.8	0.6	1.0	0.0	0.3	0.6	---	---	18" pipe in SSGS
101101B	17	G	375	223	314	131	136	200	2	0.64	1.3	0.8	1.1	0.5	0.5	0.7	---	---	18" pipe in SSGS
101101B	18	G	283	161	221	75	85	135	2	0.64	1.0	0.6	0.8	0.3	0.3	0.5	3.2	< 0.15	18" pipe in SSGS
NoMeas	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4.24	< 0.1	18" pipe in SSGS
NoMeas	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.76	< 0.11	18" pipe in SSGS
102201A	1	F	174	281	471	201	222	279	2	0.64	0.6	1.0	1.7	0.7	0.8	1.0	< 0.1	< 0.1	12" pipe into shunt
102201A	2	F	262	319	513	312	261	312	2	0.64	0.9	1.1	1.8	1.1	0.9	1.1	---	---	12" pipe into shunt
102201A	3	F	-16	259	474	-240	245	269	2	0.64	-0.1	0.9	1.7	-0.8	0.9	0.9	---	---	12" pipe into shunt
102201A	4	F	399	347	507	-215	245	277	2	0.64	1.4	1.2	1.8	-0.8	0.9	1.0	---	---	12" pipe into shunt
102201A	5	F	58	307	549	269	263	330	2	0.64	0.2	1.1	1.9	0.9	0.9	1.2	---	---	12" pipe into shunt
102201A	6	F	119	287	493	33	203	293	2	0.64	0.4	1.0	1.7	0.1	0.7	1.0	---	---	12" pipe into shunt
102201A	7	F	199	313	512	21	211	308	2	0.64	0.7	1.1	1.8	0.1	0.7	1.1	---	---	12" pipe into shunt
102201A	8	F	-150	265	427	15	169	247	2	0.64	-0.5	0.9	1.5	0.1	0.6	0.9	---	---	12" pipe into shunt
102201A	9	F	10	184	336	197	169	221	2	0.64	0.0	0.6	1.2	0.7	0.6	0.8	---	---	12" pipe into shunt
102201A	10	F	263	262	398	-152	188	216	2	0.64	0.9	0.9	1.4	-0.5	0.7	0.8	---	---	12" pipe into shunt
102201A	11	F	-39	195	345	-74	155	203	2	0.64	-0.1	0.7	1.2	-0.3	0.5	0.7	---	---	12" pipe into shunt
102201A	12	I	-89	1899	3505	830	1565	2124	1.6	2.54	-0.1	2.1	3.9	0.9	1.7	2.4	---	---	12" protruding into shunt
102201A	3D	F	317	322	488	185	228	299	2	0.64	1.1	1.1	1.7	0.7	0.8	1.1	---	---	dup-12" pipe into shunt
102201A	12D	I	-4093	2721	3432	1556	1675	2119	1.6	2.54	-4.5	3.0	3.8	1.7	1.9	2.3	---	---	dup-12" protruding into shunt
102201B	1	F	377	312	446	-275	232	237	2	0.64	1.3	1.1	1.6	-1.0	0.8	0.8	< 0.1	< 0.1	12" unknown line into shunt
102201B	2	F	-19	265	484	115	218	297	2	0.64	-0.1	0.9	1.7	0.4	0.8	1.0	---	---	12" unknown line into shunt
102201B	3	F	240	321	515	250	252	317	2	0.64	0.8	1.1	1.8	0.9	0.9	1.1	---	---	12" unknown line into shunt
102201B	4	F	219	344	565	-12	228	327	2	0.64	0.8	1.2	2.0	0.0	0.8	1.2	---	---	12" unknown line into shunt
102201B	5	F	-296	359	550	221	270	347	2	0.64	-1.0	1.3	1.9	0.8	0.9	1.2	---	---	12" unknown line into shunt
102201B	6	F	223	298	476	113	216	298	2	0.64	0.8	1.0	1.7	0.4	0.8	1.0	---	---	12" unknown line into shunt
102201B	7	F	164	224	360	200	182	236	2	0.64	0.6	0.8	1.3	0.7	0.6	0.8	---	---	12" unknown line into shunt
102201B	8	I	-588	1610	2756	-64	1097	1593	1.6	2.54	-0.7	1.8	3.1	-0.1	1.2	1.8	---	---	12" unk.protruding into shunt
102201B	8D	I	1128	1711	2795	-1971	1527	1465	1.6	2.54	1.3	1.9	3.1	-2.2	1.7	1.6	---	---	dup-12" unk.protruding into shunt
102301A	1	G	327	300	443	-35	179	250	2	0.64	1.1	1.1	1.6	-0.1	0.6	0.9	< 0.07	< 0.08	16" drain pipe from sump
102301A	2	G	277	309	480	223	233	296	2	0.64	1.0	1.1	1.7	0.8	0.8	1.0	---	---	16" drain pipe from sump
102301A	3	G	-234	309	477	171	226	297	2	0.64	-0.8	1.1	1.7	0.6	0.8	1.0	---	---	16" drain pipe from sump
102301A	4	G	135	257	432	-163	213	254	2	0.64	0.5	0.9	1.5	-0.6	0.8	0.9	---	---	16" drain pipe from sump
102301A	5	G	116	199	330	31	137	201	2	0.64	0.4	0.7	1.2	0.1	0.5	0.7	---	---	16" drain pipe from sump
102301A	6	G	-105	214	355	195	179	229	2	0.64	-0.4	0.8	1.2	0.7	0.6	0.8	---	---	16" drain pipe from sump
102301A	7	I	2540	2071	2987	275	1190	1706	1.6	2.54	2.8	2.3	3.3	0.3	1.3	1.9	---	---	12" protruding into shunt
102301B	1	B	95	145	243	40	102	155	2	0.64	0.3	0.5	0.9	0.1	0.4	0.5	0.16	< 0.08	top 8" pipe SSGS

			Pipe or Sump Surface Activity (dpm/100 sq.cm)						Est.Parameters Sediment/Scale		Concentration in Sediment or Scale (pCi/g)						GPU Laboratory Sampling Result (pCi/g)		
Pipe	Spec	Geom.	Cs-137			Co-60			Density	Thick.	Cs-137			Co-60					
	#	Model	Activity	"+-2s"	MDA	Activity	"+-2s"	MDA	(g/cc)	(cm)	Conc.	"+-2s"	MDA	Conc.	"+-2s"	MDA	Cs-137	Co-60	Description
102301B	2	B	109	145	241	-39	104	142	2	0.64	0.4	0.5	0.8	-0.1	0.4	0.5	---	---	top 8" pipe SSGS
102301B	3	B	-197	251	379	-55	171	236	2	0.64	-0.7	0.9	1.3	-0.2	0.6	0.8	---	---	top 8" pipe SSGS
102301B	4	B	200	295	471	20	193	292	2	0.64	0.7	1.0	1.7	0.1	0.7	1.0	---	---	top 8" pipe SSGS
102301B	5	B	-319	280	384	98	178	251	2	0.64	-1.1	1.0	1.4	0.3	0.6	0.9	---	---	top 8" pipe SSGS
102301B	6	B	-248	273	399	207	211	283	2	0.64	-0.9	1.0	1.4	0.7	0.7	1.0	---	---	top 8" pipe SSGS
102301B	7	B	279	283	424	-65	184	254	2	0.64	1.0	1.0	1.5	-0.2	0.6	0.9	---	---	top 8" pipe SSGS
102301B	8	D	1178	392	355	-29	118	174	2	0.64	4.1	1.4	1.2	-0.1	0.4	0.6	5.6	< 0.07	middle 6" pipe SSGS
102301B	9	D	1478	504	477	137	158	242	2	0.64	5.2	1.8	1.7	0.5	0.6	0.9	---	---	middle 6" pipe SSGS
102301B	10	D	1112	494	558	-76	235	329	2	0.64	3.9	1.7	2.0	-0.3	0.8	1.2	---	---	middle 6" pipe SSGS
102301B	10D	D	1182	436	410	4	149	231	2	0.64	4.2	1.5	1.4	0.0	0.5	0.8	---	---	dup-middle 6" pipe SSGS
102301B	11	D	518	341	448	227	185	238	2	0.64	1.8	1.2	1.6	0.8	0.7	0.8	---	---	middle 6" pipe SSGS
102301B	12	D	639	359	448	206	214	286	2	0.64	2.3	1.3	1.6	0.7	0.8	1.0	---	---	middle 6" pipe SSGS
102301B	13	B	520	230	265	-149	246	340	2	0.64	1.8	0.8	0.9	-0.5	0.9	1.2	2.3	< 0.1	bottom 8" pipe SSGS
102301B	14	B	638	254	270	-56	106	143	2	0.64	2.2	0.9	1.0	-0.2	0.4	0.5	---	---	bottom 8" pipe SSGS
102301B	15	B	520	301	384	-19	163	243	2	0.64	1.8	1.1	1.3	-0.1	0.6	0.9	---	---	bottom 8" pipe SSGS
102301B	16	B	471	324	437	4	192	296	2	0.64	1.7	1.1	1.5	0.0	0.7	1.0	---	---	bottom 8" pipe SSGS
102301B	17	B	518	332	438	-102	212	285	2	0.64	1.8	1.2	1.5	-0.4	0.7	1.0	---	---	bottom 8" pipe SSGS
102301B	18	B	-62	227	390	-20	182	274	2	0.64	-0.2	0.8	1.4	-0.1	0.6	1.0	---	---	bottom 8" pipe SSGS
102301C	1	B	-94	160	255	172	149	207	2	0.64	-0.3	0.6	0.9	0.6	0.5	0.7	0.27	< 0.06	8" SW SSGS 803
102301C	2	B	202	191	289	26	121	185	2	0.64	0.7	0.7	1.0	0.1	0.4	0.7	0.25	0.036	8" SW SSGS 803
102301C	3	B	336	209	283	-92	137	172	2	0.64	1.2	0.7	1.0	-0.3	0.5	0.6	---	---	8" SW SSGS 803
102301C	4	B	344	232	317	-71	144	192	2	0.64	1.2	0.8	1.1	-0.2	0.5	0.7	---	---	8" SW SSGS 803
102301C	5	B	394	274	380	-120	183	227	2	0.64	1.4	1.0	1.3	-0.4	0.6	0.8	---	---	8" SW SSGS 803
102301C	6	B	703	312	346	168	167	231	2	0.64	2.5	1.1	1.2	0.6	0.6	0.8	---	---	8" SW SSGS 803
102301C	6d	B	819	306	316	-172	182	207	2	0.64	2.9	1.1	1.1	-0.6	0.6	0.7	---	---	dup-8" SW SSGS 803
102301C	7	B	659	317	370	-169	183	207	2	0.64	2.3	1.1	1.3	-0.6	0.6	0.7	---	---	8" SW SSGS 803
102301C	8	B	646	306	352	-31	148	218	2	0.64	2.3	1.1	1.2	-0.1	0.5	0.8	---	---	8" SW SSGS 803
102301C	9	B	652	304	345	-147	165	191	2	0.64	2.3	1.1	1.2	-0.5	0.6	0.7	---	---	8" SW SSGS 803
102301C	9d	B	667	306	348	-78	152	201	2	0.64	2.3	1.1	1.2	-0.3	0.5	0.7	---	---	dup-8" SW SSGS 803
102301C	10	B	581	284	335	-165	173	196	2	0.64	2.0	1.0	1.2	-0.6	0.6	0.7	---	---	8" SW SSGS 803
102301C	11	B	192	201	310	120	145	205	2	0.64	0.7	0.7	1.1	0.4	0.5	0.7	---	---	8" SW SSGS 803
102301C	12	B	263	212	307	-158	169	193	2	0.64	0.9	0.7	1.1	-0.6	0.6	0.7	---	---	8" SW SSGS 803
102401A	1	G	-252	214	309	14	142	205	2	0.64	-0.9	0.8	1.1	0.0	0.5	0.7	0.11	< 0.04	Warehouse to Shunt AK131
102401A	2	G	230	220	334	-38	147	204	2	0.64	0.8	0.8	1.2	-0.1	0.5	0.7	---	---	Warehouse to Shunt AK131
102401A	3	G	231	213	325	-22	156	228	2	0.64	0.8	0.7	1.1	-0.1	0.5	0.8	---	---	Warehouse to Shunt AK131
102401A	4	G	58	177	316	-29	154	222	2	0.64	0.2	0.6	1.1	-0.1	0.5	0.8	---	---	Warehouse to Shunt AK131
102401A	5	G	193	213	336	49	155	224	2	0.64	0.7	0.7	1.2	0.2	0.5	0.8	---	---	Warehouse to Shunt AK131
102401A	6	G	343	255	363	62	158	222	2	0.64	1.2	0.9	1.3	0.2	0.6	0.8	---	---	Warehouse to Shunt AK131
102401A	7	G	143	210	346	93	156	214	2	0.64	0.5	0.7	1.2	0.3	0.5	0.8	---	---	Warehouse to Shunt AK131
102401B	1	G	60	283	503	45	207	294	2	0.64	0.2	1.0	1.8	0.2	0.7	1.0	---	---	Warehouse to Shunt AG131
102401B	2	G	6	280	516	89	222	305	2	0.64	0.0	1.0	1.8	0.3	0.8	1.1	---	---	Warehouse to Shunt AG131
102401B	3	G	-416	370	522	132	259	358	2	0.64	-1.5	1.3	1.8	0.5	0.9	1.3	---	---	Warehouse to Shunt AG131
102401B	4	G	171	308	510	67	211	296	2	0.64	0.6	1.1	1.8	0.2	0.7	1.0	---	---	Warehouse to Shunt AG131
102401B	5	G	-19	274	497	222	243	311	2	0.64	-0.1	1.0	1.8	0.8	0.9	1.1	---	---	Warehouse to Shunt AG131

Pipe	Spec #	Geom. Model	Pipe or Sump Surface Activity (dpm/100 sq.cm) Cs-137 Activity	Cs-137 "+-2s"	Cs-137 MDA	Co-60 Activity	Co-60 "+-2s"	Co-60 MDA	Est.Parameters Sediment/Scale Density (g/cc)	Thick. (cm)	Concentration in Sediment or Scale (pCi/g) Cs-137 Conc.	Cs-137 "+-2s"	Cs-137 MDA	Co-60 Conc.	Co-60 "+-2s"	Co-60 MDA	GPU Laboratory Sampling Result (pCi/g) Cs-137	Co-60	Description
102501A	1	H	-69	392	694	135	310	430	2	0.64	-0.2	1.4	2.4	0.5	1.1	1.5	---	---	Shunt at manhole at AE133
102501A	2	I	1981	2308	3534	-499	1492	2049	1.6	2.54	2.2	2.6	3.9	-0.6	1.7	2.3	---	---	Shunt at manhole at AE133
102501A	3	I	-1048	2037	3299	1671	1631	2095	1.6	2.54	-1.2	2.3	3.7	1.9	1.8	2.3	---	---	Shunt at manhole at AE133
102501B	1	I	-458	1299	2200	-741	1151	1465	1.6	2.54	-0.5	1.4	2.4	-0.8	1.3	1.6	0.04	< 0.12	Shunt intake at AE 131
102501B	1d	I	-1234	1459	2188	436	1087	1593	1.6	2.54	-1.4	1.6	2.4	0.5	1.2	1.8	"	"	dup-Shunt intake at AE 131
102501C	1	I	1381	1451	2235	428	1070	1575	1.6	2.54	1.5	1.6	2.5	0.5	1.2	1.7	0.34	< 0.09	Shunt outfall at AX 145
102501C	2	I	-1296	1480	2184	451	1075	1578	1.6	2.54	-1.4	1.6	2.4	0.5	1.2	1.7	0.27	< 0.09	
bkg100801	1	A	-46	229	406	74	208	306	2	0.64	-0.2	0.8	1.4	0.3	0.7	1.1	---	---	
bkg100801	2	A	35	283	509	29	234	355	2	0.64	0.1	1.0	1.8	0.1	0.8	1.3	---	---	
bkg100901	1	A	13	258	478	87	240	348	2	0.64	0.0	0.9	1.7	0.3	0.8	1.2	---	---	
bkg100901	2	A	-133	251	411	-5	208	320	2	0.64	-0.5	0.9	1.4	0.0	0.7	1.1	---	---	
bkg101001	1	A	36	258	464	-167	241	300	2	0.64	0.1	0.9	1.6	-0.6	0.8	1.1	---	---	
bkg101001	2	A	-5	260	473	-62	230	332	2	0.64	0.0	0.9	1.7	-0.2	0.8	1.2	---	---	
bkg101101	1	A	180	296	484	30	228	346	2	0.64	0.6	1.0	1.7	0.1	0.8	1.2	---	---	
bkg101101	2	A	111	192	320	87	148	241	2	0.64	0.4	0.7	1.1	0.3	0.5	0.8	---	---	
bkg102201	1	A	-40	222	399	12	183	278	2	0.64	-0.1	0.8	1.4	0.0	0.6	1.0	---	---	
bkg102202	2	A	192	250	395	-49	179	257	2	0.64	0.7	0.9	1.4	-0.2	0.6	0.9	---	---	
bkg102301	1	A	8	207	378	-46	170	242	2	0.64	0.0	0.7	1.3	-0.2	0.6	0.9	---	---	
bkg102301	2	A	-144	212	329	117	168	244	2	0.64	-0.5	0.7	1.2	0.4	0.6	0.9	---	---	
bkg102401	1	A	-111	202	327	33	145	219	2	0.64	-0.4	0.7	1.2	0.1	0.5	0.8	---	---	
bkg102401	2	A	104	234	402	-5	172	261	2	0.64	0.4	0.8	1.4	0.0	0.6	0.9	---	---	

Appendix C - Geometric Models & Conversion Factor Calculations

Appendix C - Geometric Models & Conversion Factor Calculations

Model #	Model Geometry	Dose Point (Detector) Position	Microshield Activity (uCi/cc)	Microshield Shield 1 (i.e., Source) Material	Dens	Thick (cm)	Microshield Fluence Rate MeV/sqcm-sec 662	1332	gam/(sqcm-sec) per (uCi/sqcm in srce) 662	1332	1x4 Det Eff(c/gam) Cs-137	Co-60	Detector Area (sq.cm)	Conversion Factor (cps/(dpm/sqcm)) Cs-137	Co-60
A	7.5" diameter pipe x 15" long	center of pipe	1.00E-06	iron	2	0.64	0.01406	0.03385	33185	39708	0.39	0.168	25.8	0.150	0.078
B	7.5" diameter pipe x 15" long	1.5" from bottom	1.00E-06	iron	2	0.64	0.0164	0.03965	38708	46511	0.39	0.168	25.8	0.175	0.091
C	5.5" diameter pipe x 11" long	center of pipe	1.00E-06	iron	2	0.64	0.01412	0.03401	33327	39895	0.39	0.168	25.8	0.151	0.078
D	5.5" diameter pipe x 11" long	1.5" from bottom	1.00E-06	iron	2	0.64	0.01537	0.03707	36277	43485	0.39	0.168	25.8	0.164	0.085
E	9.5" diameter pipe x 19" long	center of pipe	1.00E-06	iron	2	0.64	0.01402	0.03376	33091	39602	0.39	0.168	25.8	0.150	0.077
F	12" diameter pipe x 24" long	1.5" from bottom	1.00E-06	iron	2	0.64	0.01821	0.04421	42981	51860	0.39	0.168	25.8	0.195	0.101
G	18" diameter pipe x 36" long	1.5" from bottom	1.00E-06	iron	2	0.64	0.01974	0.04809	46592	56412	0.39	0.168	25.8	0.211	0.110
H	24" diameter pipe x 48" long	center of pipe	1.00E-06	iron	2	0.64	0.01381	0.03326	32595	39016	0.39	0.168	25.8	0.148	0.076
I	42" diameter pipe x 84" long	center of pipe, 12"x1" sed.layer	1.00E-06	concrete	1.6	2.54	0.01021	0.02505	6072	7404	0.39	0.168	25.8	0.028	0.014
J	21" x 35" sump floor	8" from bottom	1.00E-06	concrete	1.6	2.54	0.0166	0.04186	9872	12373	0.39	0.168	25.8	0.045	0.024
K	36" x 36" sump floor	8" from bottom	1.00E-06	concrete	1.6	2.54	0.02151	0.05463	12792	16147	0.39	0.168	25.8	0.058	0.032
L	15" diam sump floor	4" from bottom	1.00E-06	concrete	1.6	2.54	0.01829	0.04604	10877	13608	0.39	0.168	25.8	0.049	0.027
M	3.75" diam pipe x 7.5" long	center of pipe	1.00E-06	iron	2	0.64	0.01413	0.03402	33351	39907	0.39	0.168	25.8	0.151	0.078
N	3.75" diam pipe x 15" - clogged	ext.of pipe*, 4" frm center	1.00E-06	concrete	1	4.763	0.008301	0.02497	2633	3936	0.39	0.168	25.8	0.012	0.008
P	3" diam pipe x 12" - clogged	ext.of pipe*, 3.25" frm cent	1.00E-06	concrete	1	3.81	0.006458	0.01905	2560	3754	0.39	0.168	25.8	0.012	0.007

* 3/16" steel wall

Appendix D - MicroShield Printouts

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED1.MS5
Run Date: December 13, 2001
Run Time: 2:27:18 PM
Duration: 00:00:26

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "A"

Case Title: 7.5" by 15"
Description: Pipe Geometry - Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point

Source Dimensions

Height	38.1 cm	1 ft 3.0 in
Radius	8.89 cm	3.5 in

Dose Points

	X	Y	Z
# 1	0 cm	19.05 cm	0 cm
	0.0 in	7.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	8.89 in	Air	0.00122
Source	.252 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	1.3349e-009	4.9390e+001	9.4600e-007	3.5002e-002
Co-60	1.4111e-009	5.2209e+001	1.0000e-006	3.7000e-002
Cs-137	1.4111e-009	5.2209e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.023e+00	1.552e-06	1.594e-06	1.293e-08	1.328e-08
0.0322	1.887e+00	2.997e-06	3.081e-06	2.412e-08	2.480e-08
0.0364	6.865e-01	1.752e-06	1.818e-06	9.953e-09	1.033e-08
0.6616	4.444e+01	1.406e-02	1.471e-02	2.725e-05	2.851e-05
0.6938	8.516e-03	2.829e-06	2.955e-06	5.461e-09	5.706e-09
1.1732	5.221e+01	2.972e-02	3.064e-02	5.311e-05	5.476e-05
1.3325	5.221e+01	3.385e-02	3.481e-02	5.873e-05	6.040e-05
TOTALS:	1.525e+02	7.764e-02	8.017e-02	[illegible]	1.437e-04

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED2.MS5
Run Date: December 13, 2001
Run Time: 2:33:51 PM
Duration: 00:00:26

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "B"

Case Title: 7.5" by 15"
Description: Pipe Geometry - 2.25" From Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point

Source Dimensions

Height	38.1 cm	1 ft 3.0 in
Radius	8.89 cm	3.5 in

Dose Points

	X	Y	Z
# 1	5.715 cm	19.05 cm	0 cm
	2.3 in	7.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	8.89 in	Air	0.00122
Source	.252 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.3349e-009	4.9390e+001	9.4600e-007	3.5002e-002
Co-60	1.4111e-009	5.2209e+001	1.0000e-006	3.7000e-002
Cs-137	1.4111e-009	5.2209e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.023e+00	1.568e-06	1.610e-06	1.306e-08	1.341e-08
0.0322	1.887e+00	3.028e-06	3.112e-06	2.437e-08	2.505e-08
0.0364	6.865e-01	1.771e-06	1.837e-06	1.006e-08	1.044e-08
0.6616	4.444e+01	1.640e-02	1.734e-02	3.180e-05	3.361e-05
0.6938	8.516e-03	3.301e-06	3.484e-06	6.374e-09	6.726e-09
1.1732	5.221e+01	3.479e-02	3.613e-02	6.217e-05	6.456e-05
1.3325	5.221e+01	3.965e-02	4.1[illegible]4e-02	6.879e-05	7.120e-05
TOTALS:	1.525e+02	9.085e-02	9.452e-02	1.6[illegible]8e-04	1.694e-04

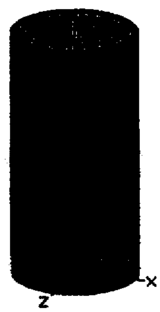
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED3.MS5
Run Date: December 13, 2001
Run Time: 2:38:24 PM
Duration: 00:00:26

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "C"

Case Title: 5.5" by 11"
Description: Pipe Geometry - Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point



Source Dimensions

Height	27.94 cm	11.0 in
Radius	6.35 cm	2.5 in

Dose Points

	X	Y	Z
# 1	0 cm	13.97 cm	0 cm
	0.0 in	5.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	6.35 in	Air	0.00122
Source	.252 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	7.0893e-010	2.6230e+001	9.4600e-007	3.5002e-002
Co-60	7.4940e-010	2.7728e+001	1.0000e-006	3.7000e-002
Cs-137	7.4940e-010	2.7728e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	10
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	5.430e-01	1.561e-06	1.603e-06	1.300e-08	1.335e-08
0.0322	1.002e+00	3.014e-06	3.098e-06	2.426e-08	2.493e-08
0.0364	3.646e-01	1.761e-06	1.827e-06	1.001e-08	1.038e-08
0.6616	2.360e+01	1.412e-02	1.477e-02	2.738e-05	2.864e-05
0.6938	4.523e-03	2.842e-06	2.968e-06	5.4[illegible]7e-09	5.731e-09
1.1732	2.773e+01	2.986e-02	3.078e-02	5.335e-05	5.501e-05
1.3325	2.773e+01	3.401e-02	3.497e-02	5.9[illegible]0e-05	6.066e-05
TOTALS:	8.097e+01	7.799e-02	8.053e-02	1.3[illegible]9e-04	1.444e-04

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED4.MS5
Run Date: December 13, 2001
Run Time: 2:44:16 PM
Duration: 00:00:26

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "D"

Case Title: 5.5" by 11"
Description: Pipe Geometry - 1.25" From Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point

Source Dimensions

Height	27.94 cm	11.0 in
Radius	6.35 cm	2.5 in

Dose Points

	X	Y	Z
# 1	3.175 cm	13.97 cm	0 cm
	1.3 in	5.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	6.35 in	Air	0.00122
Source	.252 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	7.0893e-010	2.6230e+001	9.4600e-007	3.5002e-002
Co-60	7.4940e-010	2.7728e+001	1.0000e-006	3.7000e-002
Cs-137	7.4940e-010	2.7728e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	5.430e-01	1.570e-06	1.612e-06	1.307e-08	1.343e-08
0.0322	1.002e+00	3.031e-06	3.116e-06	2.439e-08	2.508e-08
0.0364	3.646e-01	1.772e-06	1.839e-06	1.007e-08	1.045e-08
0.6616	2.360e+01	1.537e-02	1.616e-02	2.979e-05	3.132e-05
0.6938	4.523e-03	3.092e-06	3.246e-06	5.970e-09	6.268e-09
1.1732	2.773e+01	3.254e-02	3.366e-02	5.814e-05	6.016e-05
1.3325	2.773e+01	3.707e-02	3.824e-02	6.431e-05	6.635e-05
TOTALS:	8.097e+01	8.498e-02	8.807e-02	1.523e-04	1.579e-04

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED5.MS5
Run Date: December 13, 2001
Run Time: 2:50:24 PM
Duration: 00:00:26

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "E"

Case Title: 9.5" by 19"
Description: Pipe Geometry - Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point

Source Dimensions

Height	48.26 cm	1 ft 7.0 in
Radius	11.43 cm	4.5 in

Dose Points

	X	Y	Z
# 1	0 cm	24.13 cm	0 cm
	0.0 in	9.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	11.43 in	Air	0.00122
Source	.252 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	2.1571e-009	7.9814e+001	9.4600e-007	3.5002e-002
Co-60	2.2803e-009	8.4370e+001	1.0000e-006	3.7000e-002
Cs-137	2.2803e-009	8.4370e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

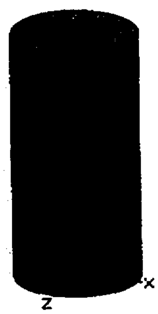
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.652e+00	1.546e-06	1.588e-06	1.288e-08	**1.323e-08**
0.0322	3.049e+00	2.986e-06	3.070e-06	2.403e-08	**2.471e-08**
0.0364	1.109e+00	1.746e-06	1.812e-06	9.918e-09	**1.029e-08**
0.6616	7.182e+01	1.402e-02	1.467e-02	2.718e-05	**2.844e-05**
0.6938	1.376e-02	2.821e-06	2.948e-06	5.446e-09	**5.691e-09**
1.1732	8.437e+01	2.964e-02	3.057e-02	5.296e-05	**5.462e-05**
1.3325	8.437e+01	3.376e-02	3.472e-02	5.857e-05	**6.024e-05**
TOTALS:	2.464e+02	7.742e-02	7.997e-02	1.388e-04	**1.434e-04**

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page	: 1	File Ref:	
DOS File:	TED6.MS5	Date:	
Run Date:	December 13, 2001	By:	
Run Time:	3:59:11 PM	Checked:	
Duration:	00:00:26		

Model "F"

Case Title: 12" by 24"
Description: Pipe Geometry - 4.5" From Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point



Source Dimensions

Height	60.96 cm	2 ft
Radius	14.605 cm	5.8 in

Dose Points

	X	Y	Z
# 1	11.43 cm	30.48 cm	0 cm
	4.5 in	1 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	14.605 in	Air	0.00122
Source	.252 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	$\mu Ci/cm^3$	Bq/cm^3
Ba-137m	3.4611e-009	1.2806e+002	9.4600e-007	3.5002e-002
Co-60	3.6586e-009	1.3537e+002	1.0000e-006	3.7000e-002
Cs-137	3.6586e-009	1.3537e+002	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate $MeV/cm^2/sec$ No Buildup	Fluence Rate $MeV/cm^2/sec$ With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	2.651e+00	1.566e-06	1.609e-06	1.305e-08	1.340e-08
0.0322	4.891e+00	3.025e-06	3.109e-06	2.434e-08	2.502e-08
0.0364	1.780e+00	1.770e-06	1.836e-06	1.005e-08	1.043e-08
0.6616	1.152e+02	1.821e-02	1.945e-02	3.531e-05	3.772e-05
0.6938	2.208e-02	3.667e-06	3.909e-06	7.080e-09	7.547e-09
1.1732	1.354e+02	3.876e-02	4.054e-02	6.927e-05	7.245e-05
1.3325	1.354e+02	4.421e-02	4.606e-02	7.669e-05	7.990e-05
TOTALS:	3.953e+02	1.012e-01	1.061e-01	1.813e-04	1.901e-04

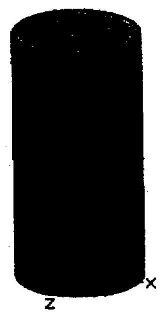
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED7.MS5
Run Date: December 13, 2001
Run Time: 4:23:50 PM
Duration: 00:00:27

File Ref: ______
Date: ______
By: ______
Checked: ______

Model "G"

Case Title: 18" by 36"
Description: Pipe Geometry - 7.5" From Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point



Source Dimensions

Height	91.44 cm	3 ft
Radius	22.225 cm	8.8 in

Dose Points

	X	Y	Z
# 1	19.05 cm	45.72 cm	0 cm
	7.5 in	1 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	22.225 in	Air	0.00122
Source	.25 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	7.7801e-009	2.8786e+002	9.4600e-007	3.5002e-002
Co-60	8.2242e-009	3.0429e+002	1.0000e-006	3.7000e-002
Cs-137	8.2242e-009	3.0429e+002	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	5.960e+00	1.564e-06	1.607e-06	1.303e-08	1.338e-08
0.0322	1.100e+01	3.021e-06	3.106e-06	2.4[illegible]1e-08	2.499e-08
0.0364	4.001e+00	1.768e-06	1.835e-06	1.0[illegible]e-08	1.043e-08
0.6616	2.590e+02	1.974e-02	2.130e-02	3.[illegible]e-05	4.130e-05
0.6938	4.964e-02	3.976e-06	4.280e-06	[illegible]e-09	8.264e-09
1.1732	3.043e+02	4.214e-02	4.440e-02	[illegible]e-05	7.934e-05
1.3325	3.043e+02	4.809e-02	5.044e-02	[illegible]e-05	8.751e-05
TOTALS:	8.886e+02	1.100e-01	1.162e-01	[illegible]e-04	2.082e-04

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED8.MS5
Run Date: December 13, 2001
Run Time: 4:21:18 PM
Duration: 00:00:27

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "H"

Case Title: 24" by 48"
Description: Pipe Geometry - Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point

Source Dimensions

Height	121.92 cm	4 ft
Radius	29.845 cm	11.8 in

Dose Points

	X	Y	Z
# 1	0 cm	60.96 cm	0 cm
	0.0 in	2 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	29.845 in	Air	0.00122
Source	.25 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	1.3880e-008	5.1356e+002	9.4600e-007	3.5002e-002
Co-60	1.4672e-008	5.4287e+002	1.0000e-006	3.7000e-002
Cs-137	1.4672e-008	5.4287e+002	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.063e+01	1.525e-06	1.566e-06	1.270e-08	1.305e-08
0.0322	1.962e+01	2.945e-06	3.028e-06	2.370e-08	2.437e-08
0.0364	7.138e+00	1.723e-06	1.789e-06	9.791e-09	1.016e-08
0.6616	4.621e+02	1.381e-02	1.447e-02	2.676e-05	2.804e-05
0.6938	8.855e-02	2.778e-06	2.907e-06	5.364e-09	5.612e-09
1.1732	5.429e+02	2.920e-02	3.014e-02	5.218e-05	5.386e-05
1.3325	5.429e+02	3.326e-02	3.424e-02	5.771e-05	5.940e-05
TOTALS:	1.585e+03	7.628e-02	7.886e-02	1.367e-04	1.414e-04

Microshield 3.12
=================
(GPU NUCLEAR CORP. - #109)

Page : 1
File : SNEC6A.MSH
Run date: December 27, ~~1999~~ 2001 TR
Run time: 9:27 a.m.

Model "I"

File Ref: ______
Date: __/__/__
By: ______
Checked: ______

CASE: 1'x1" rect.solid at bottom of 42" pipe, det.centered

GEOMETRY 11: Rectangular solid source - slab shields

Distance to detector........................	X	60.960	cm.
Source width................................	W	30.480	"
Source length...............................	L	213.360	"
Rectangular solid, thickness toward dose pt..	T1	2.540	"
Thickness of second shield..................	T2	1.270	"
Microshield inserted air gap................	air	57.150	"

Source Volume: 16518.2 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Air gap
Air			.001220
Aluminum			
Carbon			
Concrete	1.60		
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water		1.0	
Zirconium			

Model "I"

File: SNEC6A.MSH

CASE: 1'x1" rect.solid at bottom of 42" pipe, det.centered

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

Number of lateral angle segments (Ntheta)..... 5
Number of azimuthal angle segments (Npsi)..... 5
Number of radial segments (Nradius)........... 5

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	4.9554e-08	Co-60	4.9554e-08	Cs-137	4.9554e-08
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.3359	1.834e+03	2.505e-02	4.520e-05
2	1.1797	1.834e+03	2.177e-02	4.045e-05
3	.6953	2.991e-01	1.950e-06	4.016e-09
4	.6641	1.650e+03	1.021e-02	2.117e-05
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	5.317e+03	5.703e-02	1.068e-04

MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED13.MS5
Run Date: December 28, 2001
Run Time: 3:01:58 PM
Duration: 00:00:25

File Ref: ______
Date: ______
By: ______
Checked: ______

MODEL "J"

Case Title: 21" by 35" Area
Description: Sump Bottom Area - 1 in Thick Source Term
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	2.54 cm	1.0 in
Width	53.34 cm	1 ft 9.0 in
Height	88.9 cm	2 ft 11.0 in

Dose Points

	X	Y	Z
# 1	20.32 cm	44.45 cm	26.67 cm
	8.0 in	1 ft 5.5 in	10.5 in

Shields

Shield Name	Dimension	Material	Density
Source	735.0 in³	Concrete	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.1394e-008	4.2158e+002	9.4600e-007	3.5002e-002
Co-60	1.2044e-008	4.4565e+002	1.0000e-006	3.7000e-002
Cs-137	1.2044e-008	4.4565e+002	1.0000e-006	3.7000e-0

Buildup
The material reference is : Source

Integration Parameters

X Direction	40
Y Direction	40
Z Direction	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	8.728e+00	4.023e-06	4.864e-06	3.351e-08	4.052e-08
0.0322	1.610e+01	7.731e-06	9.401e-06	6.222e-08	7.566e-08
0.0364	5.860e+00	4.220e-06	5.470e-06	2.398e-08	3.108e-08
0.6616	3.793e+02	1.660e-02	2.002e-02	3.219e-05	3.881e-05
0.6938	7.269e-02	3.352e-06	4.016e-06	6.472e-09	7.754e-09
1.1732	4.456e+02	3.646e-02	4.126e-02	6.516e-05	7.373e-05
1.3325	4.456e+02	4.186e-02	4.679e-02	7.262e-05	8.118e-05
TOTALS:	1.301e+03	9.494e-02	1.081e-01	1.701e-04	1.939e-04

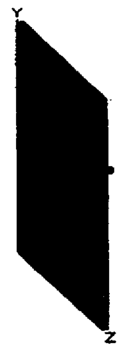
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED14.MS5
Run Date: December 28, 2001
Run Time: 3:02:56 PM
Duration: 00:00:26

File Ref: ______
Date: ______
By: ______
Checked: ______

MODEL "K"

Case Title: 36" by 36" Area
Description: Sump Bottom Area - 1 in Thick Source Term
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	2.54 cm	1.0 in
Width	91.44 cm	3 ft
Height	91.44 cm	3 ft

Dose Points

	X	Y	Z
# 1	20.32 cm	45.72 cm	45.72 cm
	8.0 in	1 ft 6.0 in	1 ft 6.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1296.0 in³	Concrete	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	2.0091e-008	7.4336e+002	9.4600e-007	3.5002e-002
Co-60	2.1238e-008	7.8579e+002	1.0000e-006	3.7000e-002
Cs-137	2.1238e-008	7.8579e+002	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

X Direction	40
Y Direction	40
Z Direction	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.539e+01	4.818e-06	5.831e-06	4.013e-08	4.857e-08
0.0322	2.839e+01	9.261e-06	1.127e-05	7.453e-08	9.073e-08
0.0364	1.033e+01	5.076e-06	6.595e-06	2.884e-08	3.747e-08
0.6616	6.689e+02	2.151e-02	2.652e-02	4.170e-05	5.141e-05
0.6938	1.282e-01	4.344e-06	5.320e-06	8.387e-09	1.027e-08
1.1732	7.858e+02	4.752e-02	5.462e-02	8.492e-05	9.761e-05
1.3325	7.858e+02	5.463e-02	6.194e-02	9.477e-05	1.075e-04
TOTALS:	2.295e+03	[illegible]	1.431e-01	2.215e-04	2.567e-04

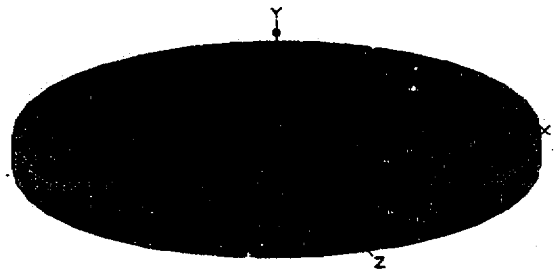
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED15.MS5
Run Date: December 28, 2001
Run Time: 3:03:54 PM
Duration: 00:00:02

File Ref: ________
Date: ________
By: ________
Checked: ________

MODEL "L"

Case Title: 15" Diameter
Description: Small Garage Sump
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	2.54 cm	1.0 in
Radius	19.05 cm	7.5 in

Dose Points

	X	Y	Z
# 1	0 cm	10.16 cm	0 cm
	0.0 in	4.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	176.715 in³	Concrete	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	2.7395e-009	1.0136e+002	9.4600e-007	3.5002e-002
Co-60	2.8958e-009	1.0715e+002	1.0000e-006	3.7000e-002
Cs-137	2.8958e-009	1.0715e+002	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	2.098e+00	4.497e-06	5.428e-06	3.745e-08	4.522e-08
0.0322	3.872e+00	8.639e-06	1.049e-05	6.952e-08	8.441e-08
0.0364	1.409e+00	4.706e-06	6.087e-06	2.674e-08	3.459e-08
0.6616	9.120e+01	1.829e-02	2.196e-02	3.546e-05	4.257e-05
0.6938	1.748e-02	3.692e-06	4.406e-06	7.129e-09	8.506e-09
1.1732	1.071e+02	4.012e-02	4.526e-02	7.169e-05	8.088e-05
1.3325	1.071e+02	4.604e-02	5.133e-02	7.988e-05	8.906e-05
TOTALS:	3.129e+02	1.045e-01	1.186e-01	1.872e-04	2.127e-04

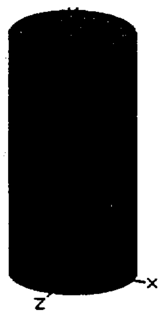
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED10.MS5
Run Date: December 13, 2001
Run Time: 4:30:12 PM
Duration: 00:00:27

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "M"

Case Title: 3.75" by 7.5"
Description: Pipe Geometry - Center of Pipe
Geometry: 11 - Annular Cylinder - Internal Dose Point



Source Dimensions

Height	19.05 cm	7.5 in
Radius	4.128 cm	1.6 in

Dose Points

	X	Y	Z
# 1	0 cm	9.525 cm	0 cm
	0.0 in	3.8 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Cyl. Core	4.128 in	Air	0.00122
Source	.25 in	Iron	2

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.1960e-010	1.1825e+001	9.4600e-007	3.5002e-002
Co-60	3.3785e-010	1.2500e+001	1.0000e-006	3.7000e-002
Cs-137	3.3785e-010	1.2500e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Source

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	2.448e-01	1.574e-06	1.617e-06	1.311e-08	1.347e-08
0.0322	4.517e-01	3.040e-06	3.125e-06	2.446e-08	2.515e-08
0.0364	1.644e-01	1.776e-06	1.842e-06	1.009e-08	1.047e-08
0.6616	1.064e+01	1.413e-02	1.478e-02	2.740e-05	2.865e-05
0.6938	2.039e-03	2.844e-06	2.969e-06	5.490e-09	5.732e-09
1.1732	1.250e+01	2.987e-02	3.079e-02	5.338e-05	5.502e-05
1.3325	1.250e+01	3.402e-02	3.497e-02	5.903e-05	6.067e-05
TOTALS:	3.650e+01	7.803e-02	8.054e-02	1.399e-04	1.444e-04

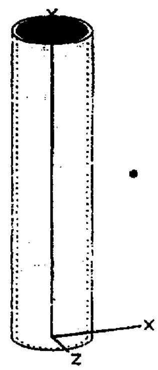
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED11.MS5
Run Date: December 13, 2001
Run Time: 4:41:09 PM
Duration: 00:00:33

File Ref: ______
Date: ______
By: ______
Checked: ______

Model "N"

Case Title: SBP - Side
Description: 3.75" D Pipe, 0.25" Wall
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	38.1 cm	1 ft 3.0 in
Radius	4.128 cm	1.6 in

Dose Points

	X	Y	Z
# 1	10.16 cm	19.05 cm	0 cm
	4.0 in	7.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	124.437 in³	Concrete	1
Shield 1	.25 in	Iron	7.86
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	1.9290e-009	7.1374e+001	9.4600e-007	3.5002e-002
Co-60	2.0391e-009	7.5449e+001	1.0000e-006	3.7000e-002
Cs-137	2.0391e-009	7.5449e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.478e+00	4.325e-22	4.782e-22	3.603e-24	3.983e-24
0.0322	2.726e+00	2.609e-21	2.893e-21	2.100e-23	2.329e-23
0.0364	9.921e-01	2.930e-17	3.327e-17	1.665e-19	1.890e-19
0.6616	6.422e+01	8.301e-03	1.463e-02	1.609e-05	2.836e-05
0.6938	1.231e-02	1.698e-06	2.951e-06	3.279e-09	5.697e-09
1.1732	7.545e+01	2.113e-02	3.173e-02	3.777e-05	5.670e-05
1.3325	7.545e+01	2.497e-02	3.631e-02	4.333e-05	6.300e-05
TOTALS:	2.203e+02	5.441e-02	8.267e-02	9.719e-05	1.481e-04

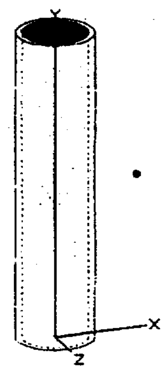
MicroShield v5.05 (5.05-00121)
GPU Nuclear

Page : 1
DOS File: TED12.MS5
Run Date: December 13, 2001
Run Time: 4:46:14 PM
Duration: 00:00:33

File Ref: ________
Date: ________
By: ________
Checked: ________

Model "P"

Case Title: SBP - Side
Description: 3" D Pipe, 0.25" Wall
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	30.48 cm	1 ft
Radius	3.175 cm	1.3 in

Dose Points

	X	Y	Z
# 1	8.255 cm	15.24 cm	0 cm
	3.3 in	6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	58.905 in³	Concrete	1
Shield 1	.25 in	Iron	7.86
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	9.1315e-010	3.3787e+001	9.4600e-007	3.5002e-002
Co-60	9.6528e-010	3.5715e+001	1.0000e-006	3.7000e-002
Cs-137	9.6528e-010	3.5715e+001	1.0000e-006	3.7000e-002

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	40
Circumferential	40
Y Direction (axial)	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	6.995e-01	4.169e-22	4.609e-22	3.473e-24	3.839e-24
0.0322	1.291e+00	2.514e-21	2.788e-21	2.023e-23	2.244e-23
0.0364	4.696e-01	2.804e-17	3.184e-17	1.593e-19	1.809e-19
0.6616	3.040e+01	6.458e-03	1.094e-02	1.252e-05	2.122e-05
0.6938	5.826e-03	1.319e-06	2.206e-06	2.547e-09	4.258e-09
1.1732	3.572e+01	1.618e-02	2.355e-02	2.891e-05	4.209e-05
1.3325	3.572e+01	1.905e-02	2.692e-02	3.305e-05	4.671e-05
TOTALS:	1.043e+02	4.169e-02	6.142e-02	7.448e-05	1.100e-04

Appendix E - Radionuclide Standard Calibration Certificates

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL MONITORING SYSTEMS LABORATORY-LAS VEGAS
P.O. BOX 93478
LAS VEGAS, NEVADA 89193-3478
702/798-2100

Calibration Certificate

Description

Principal Radionuclide	Cs-137
Total Mass of this Solution	Approx. 5 grams
Total Activity	Approx. 145 nanocuries
Half-life	30.1 years
Activity Concentration	29.0 nanocuries/gram
Date and Time of Standardization	January 23, 1995 0400 hours PST
Solution Number	94019-1

Measurement

Method of Measurement:

The activity of the primary solution was measured by four pi efficiency tracing.
The activity of the dilution was measured using gamma spectroscopy counting.

Activity of daughter radionuclide:

The principal activity was accompanied at the quoted time by :
27.4 nanocuries / gram of the daughter nuclide........ Barium-137m

Useful Life

We recommend that this solution should not be used after....... January, 2001

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards & Technology
Gaithersburg, MD 20899

REPORT OF TRACEABILITY

U.S. Environmental Protection Agency
Environmental Monitoring Systems Laboratory
Las Vegas, Nevada

Radionuclide	Cesium-137
Source identification	94019-1, prepared by EMSL
Source description	Liquid in 5-mL flame-sealed glass ampoule
Source mass	Approximately 5.0 grams
Source composition	Cesium-137 plus 100 µg of non-radioactive cesium per gram of 0.1 mol·L^{-1} HCl
Reference time	0700 EST January 23, 1995

	NIST DATA	EMSL DATA
Radioactivity concentration	1,095 Bq·g^{-1}	1,073 Bq·g^{-1}
Expanded uncertainty	0.90 percent (1,2)*	3.9 percent (3)
Photon-emitting impurities	None observed (4)	Less than 0.002 percent of the principal activity
Measuring instrument	NIST pressurized "4π"γ ionization chamber A calibrated by 4πβ-γ anti-coincidence efficiency-extrapolation technique	Four pi efficiency tracing and gamma spectroscopy
Half-life	1.102 ± 0.006 x 10^{4} days (5)	
Difference from NIST		-2.01 percent (6)

For the Director,

[signature]

J.M. Robin Hutchinson, Group Leader
Radioactivity Group
Physics Laboratory

Gaithersburg, MD 20899
September 1995

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
NATIONAL EXPOSURE RESEARCH LABORATORY
P.O. BOX 93478
LAS VEGAS, NEVADA 89193-3478

Calibration Certificate

CHARACTERIZATION RESEARCH DIVISION

Description

Principal Radionuclide	Cobalt-60
Total Mass of this Solution	Approx. 5 grams
Total Activity	Approx. 241 nanocuries
Half-life	5.271 years
Activity Concentration	48.2 nanocuries/gram
Date and Time of Standardization	March 1, 1995 0400 hours PST
Solution Number	94029-1

Measurement

Method of Measurement:

The activity of the dilution was measured using gamma spectroscopy with a germanium detector.

The activity of the primary solution was measured using gamma spectrometry.

Activity of daughter radionuclide:

The principal activity was accompanied at the quoted time by less than: ______ of the daughter nuclide ______

Useful Life

We recommend that this solution should not be used after....... January, 2004

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards & Technology
Gaithersburg, MD 20899

REPORT OF TRACEABILITY

U.S. Environmental Protection Agency
Environmental Monitoring Systems Laboratory
Las Vegas, Nevada

Radionuclide	Cobalt-60
Source identification	94029-1, prepared by EMSL
Source description	Liquid in 5-mL flame-sealed glass ampoule
Source mass	Approximately 5.0 grams
Source composition	Cobalt-60 plus 30 µg of non-radioactive Co^{++} per gram of 0.1 $mol \cdot L^{-1}$ HCl
Reference time	0700 EST March 1, 1995

	NIST DATA	EMSL DATA
Radioactivity concentration	1.774 $Bq \cdot g^{-1}$	1.783 $Bq \cdot g^{-1}$
Expanded uncertainty	0.67 percent (1,2)*	3.7 percent (3)
Photon-emitting impurities	None observed (4)	None detected
Measuring instrument	NIST pressurized "4π"γ ionization chamber A calibrated by 4πβ-γ coincidence and anti-coincidence counting	Gamma spectroscopy
Half-life	1925.5 ± 0.5 days (5)	
Difference from NIST		+0.53 percent (6)

Gaithersburg, MD 20899
September 1995

For the Director,

J.M. Robin Hutchinson, Group Leader
Radioactivity Group
Physics Laboratory

CERTIFICATE OF RADIOACTIVITY CALIBRATION

Isotope: Co-60

Half-Life: 5.2714 ± 0.0005 y

Source No.: K-400

Was assayed as containing: 1.231 mCi

As of: July 1, 1988

METHOD OF CALIBRATION:

( ) The source was assayed on a 3" x 3" NaI (TI) crystal in conjunction with a single-channel analyzer, using the MeV peak (a value of gamma rays per decay was used in the calculations), against standard No. , in the same geometrical arrangement.

( ) The source was assayed in an internal proportional/large area, low background counter against standard No.

( ) The source was assayed by alpha spectrometry on a surface barrier detector in conjunction with a single-channel analyzer, against standard No. in the same geometrical arrangement.

( ) The source was prepared from a weighed aliquot of a solution whose activity in uCi/gm was determined by the method indicated above.

(x) The source was assayed in a pressurized well type ionization chamber against Co-60 std. No. 19151.

ERROR CALCULATION:

a) Uncertainty due to systematic errors:
1. In assay of standard: ± %
2. In weighing(s): ± %

b) Uncertainty due to random errors:
Precision of source count, e_1; standard count e_2 and background count e_3:
$= \pm t \sqrt{e_1^2 + e_2^2 + e_3^2} = \pm$ %

(c) Total uncertainty:
TU = a + b = ± 5.0 %

NOTES

IPL participates in a NBS measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NBS certification) of Standard Reference Materials. (As in NRC Regulatory Guide 4.15)

(x) The total uncertainty is calculated at the 95 % confidence level.
( ) This calibration is directly/indirectly based on NBS Standard Reference Material No.

Michael Devine
Quality Control

ISOTOPE PRODUCTS LABORATORIES
1800 No. Keystone St., Burbank, California 91504

GPU Nuclear

Memorandum

Subject: Source Correlation

Date: October 18, 1985
4550-85-0291

From: Data Management and Analysis
Engineer, B. B. Brosey

Location: Three Mile Island
Unit 2

To: Data Management and Analysis
Supervisor, C. H. Distenfeld

A preliminary correlation between our ^{137}Cs calibration sources has been performed. The EG&G supplied source (800 μCi ^{137}Cs) was compared with the Amersham supplied source (11.44 μCi ^{137}Cs). The results of this comparison indicate that the observed variation is approximately 3%.

The EG&G source is incapsulated in stainless steel and aluminum. A correction must be applied to this source and the equivalent activity is dependant on which end one counts. However, side on calibrations should produce consistent values.

EG&G Source Attenuation Calculation:

$\rho_{s.s.} \cong 7.86 \frac{g}{cm^3}$, $s.s = 0.0738 \frac{cm^2}{g}$

$\rho_{Al} = 2.699 \frac{g}{cm^3}$, $Al = 0.075024 \frac{cm^2}{g}$

	Percent Transmission
S.S. capsule top 0.381cm thick	80.2%
S.S. capsule sides and bottom 0.254cm thick	86.3%
Al capsule top 0.762cm thick	85.7%
Al capsule sides and bottom 0.635cm thick	87.9%

∴ combined transmission

S.S. 0.863 x Al 0.879 = 0.759 x 789.3 μCi (Decayed to October 1, 1985)
= 599.1 μCi equivalent

Amersham source = 11.44 μCi (October, 1985)

The comparison was performed in our designated location in the auxiliary building. The sources were placed at 1 foot from the nose of our 1.5 inch radius lead attenuated sodium iodide detector assembly, using the Davidson MCA with the high voltage supply attached.

The Amersham source showed a cesium peak in Channel 105 for a 7010 second count. For a 10 channel region of interest from 105 to 115 (1/2 peak value), the total counts were 424.

$$\therefore \quad \frac{424 \text{ counts in ROI}}{7010 \text{ seconds}} = 0.060485 \frac{c}{s}$$

For the EG&G source, under the same conditions, the ROI (107-117) for 10 channels showed 2611 counts.

$$\therefore \quad \frac{2611 \text{ counts in ROI}}{1000 \text{ seconds}} = 2.611 \frac{c}{s}$$

Background for this areas - (CH 96-106 ^{137}Cs Detectable) =

$$\frac{598 \text{ counts in ROI}}{64{,}500 \text{ seconds}} = 0.0092713 \frac{c}{s}$$

	Gross		Bkgnd		Net
Amersham source	0.060485 c/s	-	0.0092713 c/s	=	0.051214 c/s
EG&G source	2.611 c/s	-	0.0092713 c/s	=	2.60173 c/s

Am. Activity $\frac{0.051214 \text{ c/s}}{11.44\ \mu Ci} : \frac{2.60173 \text{ c/s}}{X\ \mu Ci}$ ∴ X = $\frac{581.2\ \mu Ci: \text{EG\&G } ^{137}Cs}{599.1\ \mu Ci \text{ Reported}}$

97.01% Reported error (EG&G) was ± 5%

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Appendix F – Gamma Spectrometer Quality Assurance Checks

Appendix E - Gamma Spectrometer Quality Assurance Checks

SOURCE AND BACKGROUND CHECKS:

Date	Spec# [1]	Location	Note	COUNT RATE - CPS		% from mean
				662 keV [2]	662 BKG[3]	662 keV
10/8/2001	1	garage	w/ 30'cable	18.0	7.9	-2.8
10/8/2001	2	garage	w/ 30'cable	18.1	9.5	-2.2
10/9/2001	1	garage	w/ 30'cable	18.6	10.9	0.5
10/9/2001	2	garage	w/ 30'cable	18.7	8.2	1.0
10/10/2001	1	garage	w/ 30'cable	18.3	10.5	-1.2
10/10/2001	2	garage	w/ 30'cable	17.8	11.2	-3.9
10/11/2001	1	garage	w/ 30'cable	18.2	11.4	-1.7
10/11/2001	3	garage	w/ 50'cable	18.9	no reading	2.1
10/11/2001	2	SSGS '	w/ 50'cable	18.6	2.6	0.5
10/22/2001	1	garage	w/ 30'cable	20.0	7.5	8.0
10/22/2001	2	garage	w/ 30'cable	18.7	7.5	1.0
10/23/2001	1	garage	w/ 30'cable	18.3	6.9	-1.2
10/23/2001	2	SSGS 803'	w/ 30'cable	18.7	5.4	1.0
10/24/2001	1	SSGS 803'	w/ 30'cable	18.4	5.2	-0.6
10/24/2001	2	garage	w/ 30'cable	18.6	7.6	0.5
10/25/2001	1	garage	w/ 30'cable	18.7	9.9	0.9
10/25/2001	2	garage	w/ 30'cable	18.2	7.4	-1.7
			Mean:	18.5	8.1	

1 - 1=AM, 2=PM, 3=misc

2 - net photpeak count rate using GPU source #557 (Cs-137, 1.06 uCi, 10/8/82); counting time = 10 min.; distance = 12"

3 - gross count rate in Cs-137 ROI from background spectra, also listed at bottom of Appendix B

DUPLICATE READINGS:

Pipe ID	Spec#	Estimated Concentration in Sediment or Scale (pCi/g)						Difference (fraction of 1-sigma)	
		Cs-137			Co-60				
		Conc.	"+-2s"	MDA	Conc.	"+-2s"	MDA	Cs-137	Co-60
101001 C	1	1.5	1.5	2.3	0.0	0.9	1.3	< MDA	< MDA
"	1D	2.2	1.6	2.3	-0.2	0.9	1.3		
102201A	3	-0.1	0.9	1.7	-0.8	0.9	0.9	< MDA	< MDA
"	3D	1.1	1.1	1.7	0.7	0.8	1.1		
102201A	12	-0.1	2.1	3.9	0.9	1.7	2.4	< MDA	< MDA
"	12D	-4.5	3.0	3.8	1.7	1.9	2.3		
102201B	8	-0.7	1.8	3.1	-0.1	1.2	1.8	< MDA	< MDA
"	8D	1.3	1.9	3.1	-2.2	1.7	1.6		
102301B	10	3.9	1.7	2.0	-0.3	0.8	1.2	0.3	< MDA
"	10D	4.2	1.5	1.4	0.0	0.5	0.8		
102301C	6	2.5	1.1	1.2	0.6	0.6	0.8	0.7	< MDA
"	6D	2.9	1.1	1.1	-0.6	0.6	0.7		
102301C	9	2.3	1.1	1.2	-0.5	0.6	0.7	0.1	< MDA
"	9D	2.3	1.1	1.2	-0.3	0.5	0.7		
102501B	1	-0.5	1.4	2.4	-0.8	1.3	1.6	< MDA	< MDA
"	1D	-1.4	1.6	2.4	0.5	1.2	1.8		