APPENDIX 5

PRELIMINARY DESIGN OF CONVEYOR-MOUNTED DETECTION SYSTEM

ATG INC.

CALCULATION COVER SHEET

CALC. NO. MCAB-01
No. of Sheets: 1 of 76

PROJECT: Fort McClellon Burial Mound Decommissioning

PURPOSE: Calculate the performance of a conveyor-mounted detector system, scanning soil with potential cobalt-60 and cesium-137 contamination.

SOURCES OF DATA: Preliminary design of conveyor system - Lake City Project Manager, Frank Whitaker

SOURCES OF FORMULAE & REFERENCES: Multi-Agency Radiation Survey and Site Investigation Manual, MARSSIM (NUREG-1575) December, 1997.

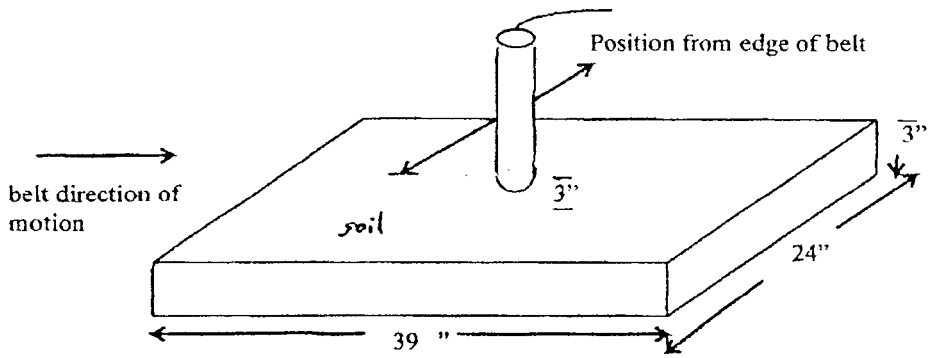
ATTACHMENT: Summary of hand calculations and output from Microshield™ runs.

CONCLUSION: System minimum detectable count rate (MDCR) is approx. 676 cpm (net). This will allow detection of Co-60 at 1.5 pCi/g or 135 nCi discrete source; or Cs-137 at 2.8 pCi/g or 80 nCi discrete source.

PRELIMINARY CALC. ☐ FINAL CALC. ☐ SUPERSEDES CALC. NO. _____

REV. NO.	REVISION	BY:	DATE	CHECKED	DATE	APPROVED	DATE

Calculation MCAB-01



CONVEYOR-MOUNTED DETECTOR MODEL

DIMENSIONS:

24" wide
belt moves at 0.5 m/s; covers 1m (39") in 2sec. counting interval
soil 3" high on belt
detectors mounted 6" above belt
10 2x2 NaI detectors cover width of belt

ASSUMPTIONS:

Soil is uniformly contaminated at 1 pCi Co-60/gram soil (Case 1.)
Soil is uniformly contaminated at 5 pCi Cs-137/gram soil (Case 2.)
Soil covers a 5 uCi point source of Co-60 (Case 3.)
Soil covers a 5 uCi point source of Cs-137 (Case 4.)

Summary of four Cases shown below, followed by discussion of detectability.

CASE 1:

Four detector positions modeled with Microshield Ver. 5. 1) center of belt (12" from edge); 2) 9" from edge; 3) 6" from edge; and 4) 3" from edge.

Mirror-image positions are the same for distances from the other side of the belt. Ignore soil on belt, which is further than 19.5" from detectors.

Microshield results show dose rate fairly constant across width of belt. Average dose rate 1.08 uR/hr, from soil at 1 pCi-Co-60/gram. Using a dose rate to count rate conversion of 430 cpm/uR/hr[1], gives 464 cpm (net.)

[1] MARSSIM Table 6-7.

Calculation MCAB-01

CASE 2:

Same detector geometry.

Microshield results show dose rate fairly constant across width of belt. Average dose rate 1.32 uR/hr, from soil at 5 pCi-Cs-137/gram. Using a dose rate to count rate conversion of 900 cpm/uR/hr[2], gives 1188 cpm (net.)

Results are scalable to other concentrations of Cs-137.

CASE 3:

In this case, a point source of Co-60 travels towards and under the detectors. Width of the belt is not considered, because the particle will pass directly under one of the detectors. It is assumed to be under the 3" of soil. Since Ludlum ratemeters integrate for 2 seconds, the particle will travel 1m (39") in that time.

Seven particle positions are modeled, from 19.7" in front of the detectors to 19.7" after the detectors. The average dose rate of the seven is 58.1 uR/hr, as shown; yielding a count rate of 24,983 cpm.

Distance from Detectors	Dose Rate uR/hr
±19.7"	7.8
±13.0	23.7
±6.6	87.0
0	222.1
Average	58.1

CASE 4:

The geometry is the same as Case 3. The point source in this case is 5 uCi Cs-137.

The average dose rate is 16.4 uR/hr, as shown; yielding a count rate of 14,760 cpm.

Distance from Detectors	Dose Rate uR/hr
±19.7"	1.9
±13.0	5.4
±6.6	21.8
0	56.9
Average	16.4

[2] MARSSIM Table 6-7.

Calculation MCAB-01

DETECTABILITY - MINIMUM DETECTABLE COUNT RATE (MDCR)

The scanning MDCR applies both to a detector moving along the ground, as well as soil on a conveyor belt moving under a detector. This MDCR is a function of background count rate, observation interval and confidence level (d'). As shown on the hand calculation sheet, MDCR is 676 cpm (net) for a background of 8,000 cpm and 2sec observation interval.

SUMMARY

Case	Calc'ed Count Rate (net)	MDCR (net)	Detectable Amount*
1	464 cpm	676	1.5 pCi/g
2	1188	676	2.8 pCi/g
3	24,983	676	135 nCi
4	14,760	676	229 nCi

* Concentration or source strength, ratioed to MDCR.

MDCR
(MARSSIM eqn. 6-9)

$MDCR = S_i \times 60/i$

$S_i = d' \sqrt{b_i}$

$i = 2sec$ obs. interval

$d' = 1.38$ (per MARSSIM)

$b_i = 8000 cpm \times 2/60 = 267$

$S_i = \sqrt{b_i} \times 1.38 = 22.5$

$MDCR = 22.5 \times 60/2 = 676$ cpm

CASE 1

MICROSHIELD OUTPUT

Soil with 1 pCi Co-60 per gram.

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: Case 1
Case Title: Co-veyor - I
This case was run on Monday, November 23, 1998 at 11:19:41 AM
Dose Point # 1 - (6,19.5,12) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	4.999e-001	4.319e-005	2.997e-005	5.785e-008
2	1.1732	3.065e+003	2.672e-001	3.135e-001	5.602e-004
3	1.3325	3.065e+003	2.681e-001	3.573e-001	6.199e-004
	TOTALS:	6.130e+003	5.354e-001	6.708e-001	1.180e-003

MicroShield v5.01 (5.01-01003) 11/23/98

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: Case 1
Case Title: Co-veyor
This case was run on Monday, November 23, 1998 at 11:19:41 AM
Dose Point # 2 - (6,19.5,9) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	4.999e-001	4.237e-005	2.940e-005	5.676e-008
2	1.1732	3.065e+003	2.622e-001	3.076e-001	5.496e-004
3	1.3325	3.065e+003	2.631e-001	3.506e-001	6.082e-004
	TOTALS:	6.130e+003	5.253e-001	6.582e-001	1.158e-003

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: Case 1
Case Title: Co-veyor
This case was run on Monday, November 23, 1998 at 11:19:41 AM
Dose Point # 3 - (6,19.5,6) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	4.999e-001	3.964e-005	2.751e-005	5.311e-008
2	1.1732	3.065e+003	2.455e-001	2.880e-001	5.146e-004
3	1.3325	3.065e+003	2.464e-001	3.283e-001	5.696e-004
	TOTALS:	6.130e+003	4.919e-001	6.163e-001	1.084e-003

MicroShield v5.01 (5.01-01003)

11/23/98

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: Case 1
Case Title: Co-veyor
This case was run on Monday, November 23, 1998 at 11:19:41 AM
Dose Point # 4 - (6,19.5,3) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	4.999e-001	3.416e-005	2.370e-005	4.576e-008
2	1.1732	3.065e+003	2.120e-001	2.487e-001	4.445e-004
3	1.3325	3.065e+003	2.130e-001	2.838e-001	4.923e-004
	TOTALS:	6.130e+003	4.250e-001	5.325e-001	9.369e-004

CASE 2

MICROSHIELD OUTPUT

Soil with 5 pCi Cs-137 per gram.

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO_VEYOR.MS5
Case Title: Conveyor - Cesium
This case was run on Monday, November 23, 1998 at 11:31:07 AM
Dose Point # 1 - (6,19.5,12) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.001e+002	1.816e-003	5.776e-005	4.812e-007
2	0.0322	5.537e+002	3.472e-003	1.118e-004	8.996e-007
3	0.0364	2.015e+002	1.828e-003	6.653e-005	3.780e-007
4	0.6616	1.304e+004	1.127e+000	7.458e-001	1.446e-003
	TOTALS:	1.410e+004	1.134e+000	7.461e-001	1.448e-003

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO_VEYOR.MS5
Case Title: Conveyor - Cesium
This case was run on Monday, November 23, 1998 at 11:31:07 AM
Dose Point # 2 - (6,19.5,9) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.001e+002	1.794e-003	5.709e-005	4.755e-007
2	0.0322	5.537e+002	3.432e-003	1.105e-004	8.891e-007
3	0.0364	2.015e+002	1.806e-003	6.574e-005	3.735e-007
4	0.6616	1.304e+004	1.106e+000	7.317e-001	1.418e-003
	TOTALS:	1.410e+004	1.113e+000	7.319e-001	1.420e-003

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO_VEYOR.MS5
Case Title: Conveyor - Cesium
This case was run on Monday, November 23, 1998 at 11:31:07 AM
Dose Point # 3 - (6,19.5,6) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.001e+002	1.714e-003	5.453e-005	4.542e-007
2	0.0322	5.537e+002	3.278e-003	1.055e-004	8.492e-007
3	0.0364	2.015e+002	1.724e-003	6.277e-005	3.566e-007
4	0.6616	1.304e+004	1.035e+000	6.846e-001	1.327e-003
	TOTALS:	1.410e+004	1.041e+000	6.848e-001	1.329e-003

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO_VEYOR.MS5
Case Title: Conveyor - Cesium
This case was run on Monday, November 23, 1998 at 11:31:07 AM
Dose Point # 4 - (6,19.5,3) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.001e+002	1.497e-003	4.763e-005	3.968e-007
2	0.0322	5.537e+002	2.863e-003	9.217e-005	7.418e-007
3	0.0364	2.015e+002	1.504e-003	5.475e-005	3.111e-007
4	0.6616	1.304e+004	8.913e-001	5.897e-001	1.143e-003
	TOTALS:	1.410e+004	8.972e-001	5.899e-001	1.145e-003

CASE 3

MICROSHIELD OUTPUT

5 uCi, Co-60 point source

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cobalt point source
This case was run on Monday, November 23, 1998 at 11:41:43 AM
Dose Point # 1 - (6.5,1.97e+01,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	3.018e+001	2.408e-004	1.671e-004	3.226e-007
2	1.1732	1.850e+005	1.734e+000	2.035e+000	3.636e-003
3	1.3325	1.850e+005	1.809e+000	2.411e+000	4.183e-003
	TOTALS:	3.700e+005	3.544e+000	4.446e+000	7.819e-003

MicroShield v5.01 (5.01-01003) 11/23/9

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cobalt point source
This case was run on Monday, November 23, 1998 at 11:41:43 AM
Dose Point # 2 - (6,1.30e+01,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	3.018e+001	8.136e-004	5.645e-004	1.090e-006
2	1.1732	1.850e+005	5.315e+000	6.236e+000	1.114e-002
3	1.3325	1.850e+005	5.430e+000	7.235e+000	1.255e-002
	TOTALS:	3.700e+005	1.075e+001	1.347e+001	2.370e-002

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cobalt point source
This case was run on Monday, November 23, 1998 at 11:41:43 AM
Dose Point # 3 - (6,6.57e+00,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	3.018e+001	3.240e-003	2.248e-003	4.340e-006
2	1.1732	1.850e+005	1.971e+001	2.312e+001	4.131e-002
3	1.3325	1.850e+005	1.976e+001	2.633e+001	4.567e-002
	TOTALS:	3.700e+005	3.947e+001	4.945e+001	8.699e-002

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cobalt point source
This case was run on Monday, November 23, 1998 at 11:41:43 AM
Dose Point # 4 - (6,0,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.6938	3.018e+001	8.446e-003	5.860e-003	1.131e-005
2	1.1732	1.850e+005	5.041e+001	5.914e+001	1.057e-001
3	1.3325	1.850e+005	5.034e+001	6.707e+001	1.164e-001
	TOTALS:	3.700e+005	1.008e+002	1.262e+002	2.221e-001

CASE 4

MICROSHIELD OUTPUT

5 uCi, Cs-137 point source

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cesium point source
This case was run on Monday, November 23, 1998 at 12:51:49 PM
Dose Point # 1 - (6.5,1.97e+01,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.623e+003	1.092e-018	3.475e-020	2.895e-022
2	0.0322	6.685e+003	7.388e-018	2.378e-019	1.914e-021
3	0.0364	2.433e+003	1.979e-013	7.204e-015	4.093e-017
4	0.6616	1.575e+005	1.240e+000	8.203e-001	1.590e-003
	TOTALS:	1.702e+005	1.240e+000	8.203e-001	1.590e-003

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cesium point source
This case was run on Monday, November 23, 1998 at 12:51:49 PM
Dose Point # 2 - (6,1.30e+01,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.623e+003	8.047e-014	2.560e-015	2.133e-017
2	0.0322	6.685e+003	3.958e-013	1.274e-014	1.026e-016
3	0.0364	2.433e+003	6.913e-010	2.516e-011	1.430e-013
4	0.6616	1.575e+005	4.232e+000	2.800e+000	5.428e-003
	TOTALS:	1.702e+005	4.232e+000	2.800e+000	5.428e-003

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cesium point source
This case was run on Monday, November 23, 1998 at 12:51:49 PM
Dose Point # 3 - (6,6.57e+00,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.623e+003	2.385e-008	7.588e-010	6.321e-012
2	0.0322	6.685e+003	8.197e-008	2.639e-009	2.124e-011
3	0.0364	2.433e+003	6.391e-006	2.326e-007	1.322e-009
4	0.6616	1.575e+005	1.698e+001	1.123e+001	2.178e-002
	TOTALS:	1.702e+005	1.698e+001	1.123e+001	2.178e-002

MicroShield v5.01 (5.01-01003)
Allied Technology Group, Inc.
Results With Buildup
FILE: C:\JOEL\MS5\DATA\CO2VEYOR.MS5
Case Title: Cesium point source
This case was run on Monday, November 23, 1998 at 12:51:49 PM
Dose Point # 4 - (6,0,0) in

Group #	Energy (MeV)	Activity photons/sec	Fluence Rate photons/cm²/sec	Energy Fluence MeV/cm²/sec	Exposure Rate mR/hr
1	0.0318	3.623e+003	2.497e-005	7.945e-007	6.618e-009
2	0.0322	6.685e+003	7.046e-005	2.268e-006	1.826e-008
3	0.0364	2.433e+003	1.003e-003	3.652e-005	2.075e-007
4	0.6616	1.575e+005	4.436e+001	2.935e+001	5.690e-002
	TOTALS:	1.702e+005	4.436e+001	2.935e+001	5.690e-002

Soil Monitoring System

Throughput:

3" Deep .25' max depth of material
24" Wide 2.0' (action belt width)
1.5 ft per sec (0.45 m/sec) max travel speed for rec. sensitivity (~1.5 pCi/gm Co-60)

.25' x 2.0' x 1.5' sec x 60 sec/min x 60 min/hr
= 2700 CF / hr
= 100 CY / hr MAX

Correction factors allocated:

1. .8 3" is max depth at bottom of concave conveyor belt only. Depth diminishes in both directions toward the sides.

2. .8 Throughput interruptions attributed to positive alarms and subsequent material marking, sorting, and restarts.

3. .8 System start-up / shut-down operation QC - achieve 8 hrs productive effort over 10 hr work day.

4. .5 Weather related delays, system obstruction, equipment failure.

100 cy/hr x 0.8 x 0.8 x 0.8 x 0.5 = ~25 cy/hr