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Spreader Bar Radiation Detection Project Data Collection Report

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Abstract

A feasibility assessment of spreader-bar radiation detection (SBRD) systems was commissioned by NA-22 in the summer of 2009. To validate modeling results and allow performance to be based on actual measurements, a full-scale mockup of a SBRD system was built. The full-scale mockup consists of an actual spreader instrumented with 32 sodium iodide gamma detectors.

Two sets of data collections were performed using the SBRD mockup. The first set measured the uniformity of radiation detection throughout the Inter-Modal Cargo Container (IMCC). The second set of data collections measured the response of the system to shielded sources. Plywood was used as the simulated cargo (shielding) material and sources were placed at varying depths within it. Both sets of data collections were performed using a forty-foot and a twenty-foot IMCC. In all, over 8700 spectra were collected during the October 2011 through December 2011 time period.

This effort is a partnership between Sandia National Laboratories (SNL) and Pacific Northwest National Laboratory (PNNL). Sandia was responsible for design and construction of the SBRD mockup and collection of the data. PNNL was responsible for design of the data collection plan and analysis of the collected data.

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NOMENCLATURE

DOE	Department of Energy
IMCC	Inter-Modal Cargo Containers
PNNL	Pacific Northwest National Laboratory
SBRD	Spreader Bar Radiation Detection
SNL	Sandia National Laboratories
TEAMS	Technical Evaluation Assessment Monitor Site

1 OBJECTIVE

The objective of the spreader bar radiation detection (SBRD) system measurements at the Technical Evaluation Assessment Monitor Site (TEAMS) is to validate the MCNP model for the SBRD project. Several different measurement configurations were performed. Experimental results will be compared to the model to confirm that the model can accurately predict performance of the SBRD system.

The SBRD measurements used gamma-ray radiation sources at the TEAMS facility to map out the radiation response within two Inter-Modal Cargo Containers (IMCCs) of different sizes, and measure response of the SBRD system to radiation sources with simulated cargo material and configurations.

2 GENERAL LIMITATIONS

The TEAMS measurements are a very limited experiment of the SBRD system and are only meant to serve the purpose of validating the MCNP simulation model of the system. The results are only applicable to the as-built and modeled SBRD system and are not applicable to other similar, commercially available systems. These measurements do not represent a complete set of system tests in terms of:

- Robustness and Reliability
- False alarm rates for stream of commerce
- Compliance with any standards for acceptance testing
- Capability to detect and identify special nuclear materials
- Conduct of operations for field operations (CONOPS)
- Operational Testing

If the SBRD system is considered for further evaluation, these aspects will be tested as part of follow-on test programs.

3 ASSUMPTIONS

The plan and procedure for the measurements had the following assumptions in regards to the measurements performed:

- Each detector in the SBRD system writes to an independent file during each measurement.
- All detectors remain in the same position (within the two configurations) for all measurements.
- Recorded spectra are stored in a single directory for each measurement, with a file for each detector.
- Spectra can be viewed in real-time, such that changes to the measurement plan and data collection can be made as needed (e.g., weak sources).
- All measurements are static with the containers on the ground.

All of the assumptions were correct.

4 GENERAL CONSTRAINTS

Although testing of the ruggedness of the SBRD system is not a specific goal, system malfunctions during the period of the measurements were documented. i.e. detectors that were off-line were noted.

The cargo containers used during measurements to emulate cargo shielding represent the typical container types used in transporting goods on container ships. Two container lengths of 20 and 40 feet were used, spanning the length of typically used containers. The height of the containers was the same height (8.5 feet). Refrigerated containers were not used, as system performance evaluation is not part of the objectives of these measurements at this time.

5 SBRD SYSTEM

The SBRD system consists of an Earl's Model 880 spreader with 32, 2" dia. by 18" long NaI detectors and associated electronics mounted on it.

Figure 1 Photo of SBRD system on test stands

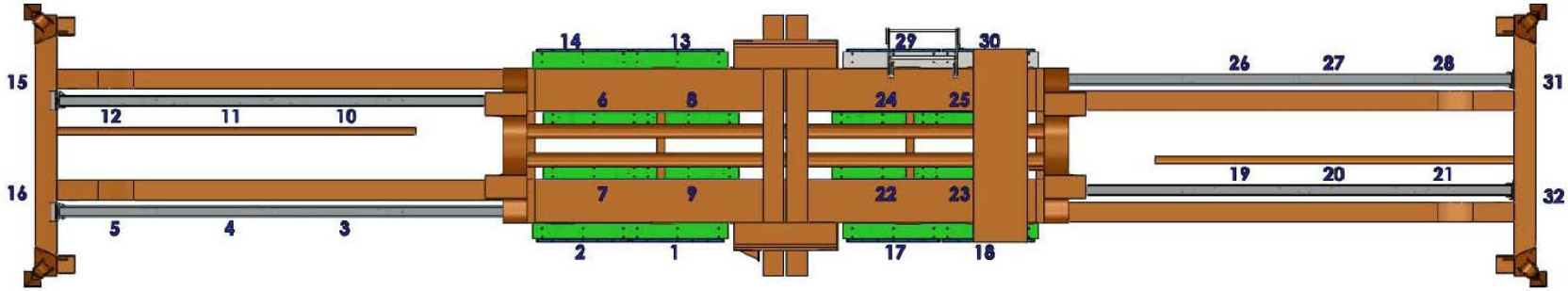


Figure 2 Diagram of detector numbering and locations (Top View)

6 TEST RESOURCES

6.1 Test Location

The measurements were conducted at the TEAMS facility in October through December, 2011. TEAMS is a Defense Threat Reduction Agency facility located on Kirtland Air Force Base, Albuquerque, NM.

Figure 3 Measurement Location at TEAMS

The location for the measurements was the southwest corner of the TEAMS facility. IMCC's and a van used for the collection of data were setup on the dirt areas.

6.2 Equipment

The hardware required for measurements with the SBRD system included:

- Shipping containers: 20 and 40 foot container lengths (one of each), each being 8.5 feet in height.

- Simulated cargo to attenuate radiation from sources (to emulate cargo shielding) as described in Section 6.2.1. Simulated cargo was constructed at PNNL, transported to the TEAMS and was loaded into empty containers prior to the start of shielding measurements.
- Radioactive sources: five gamma-ray emitting. These radioactive sources represent those isotopes typically used to test and calibrate existing radiation portal monitors at ports of entry. The sources are ^{57}Co, ^{133}Ba, ^{60}Co, ^{166m}Ho and ^{137}Cs. The activities of these sources (Table 1) are from the TEAMS and SNL source inventory.

Figure 4 Forty-foot container

Figure 5 Simulated cargo, i.e. wood blocks

Table 1. List of Sources Available for IMCC Model Validation Measurements

Source	ID	Serial #	Source Activity as of 20 Oct 2011 (µCi)
Cs-137	2912	948-37-4	24.30
	2913	948-37-2	24.62
	2914	948-37-3	23.37
	2938	948-37-1	24.34
	09-26	1FO6-12	9.39
	09-27	1FO6-13	9.39
	09-28	1FO6-14	9.39
	09-29	1FO6-15	9.39
	09-30	1FO6-16	9.39
	Secondary DTRA Source		1.43
	Secondary DTRA Source		8.48
	RS870	113432	263.92
Total Activity			**417.41**
Co-57	09-6	IFO9-1	1.51
	09-7	IFO9-2	1.51
	09-8	IFO9-3	1.51
	09-9	IFO9-4	1.51
	09-10	IFO9-5	1.51
	09-11	IFO9-6	1.51
	09-12	IFO9-7	1.51
	09-13	IFO9-8	1.51
	09-14	IFO9-9	1.51
	09-15	IFO9-10	1.51
Total Activity			**15.10**
Ba-133	2934	948-35-1	16.96
	2935	948-35-2	15.36
	2936	948-35-3	15.87
	2937	948-35-4	16.48
	09-01	1FO8-1	8.33
	09-02	1FO8-2	8.33
	09-03	1FO8-3	8.33
	09-04	1FO8-4	8.33
	09-05	1FO8-5	8.33
	RS1616	K422	264.00
Total Activity			**370.32**
Ho-166m	RS887	16238	41.10
Co-60	RS1149		47.0

6.2.1 Experimental Configurations for Simulated Cargo

Cargo will attenuate the radiation from a source, if the source is located within the cargo. Therefore, simulated cargo will be used during some measurements to provide realistic, easy to simulate attenuation of radiation from sources. The measurements will utilize 1 set of four 4x7x3.5 ft^3 simulated cargo cubes (plywood). An additional set of blocks made from high density fiberboard is available for additional measurements, if needed. Sources will be introduced within the simulated cargo by means of access ports (Figure 1) that will allow the source to be positioned within the centerline of the cube of cargo. Access ports were designed into several of the blocks on pallets to allow a source introduction every 12 inches (1 foot). The

access ports were only made in the lower quadrant of the cube due to the symmetry of the SBRD system and the cargo containers.

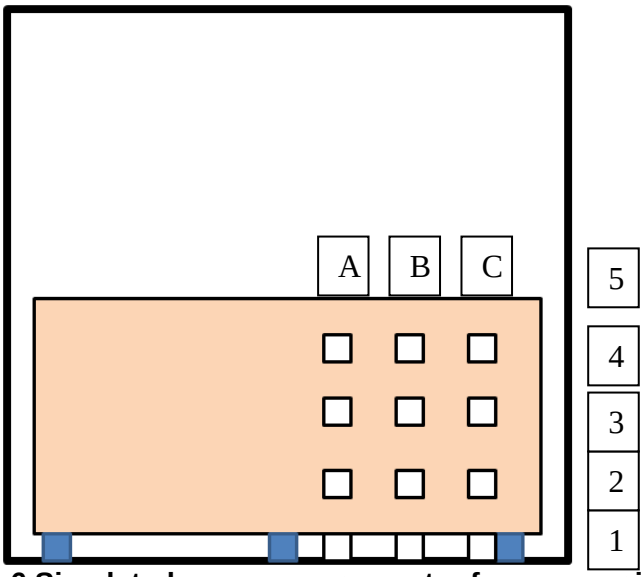


Figure 6 Simulated cargo access port reference positions.

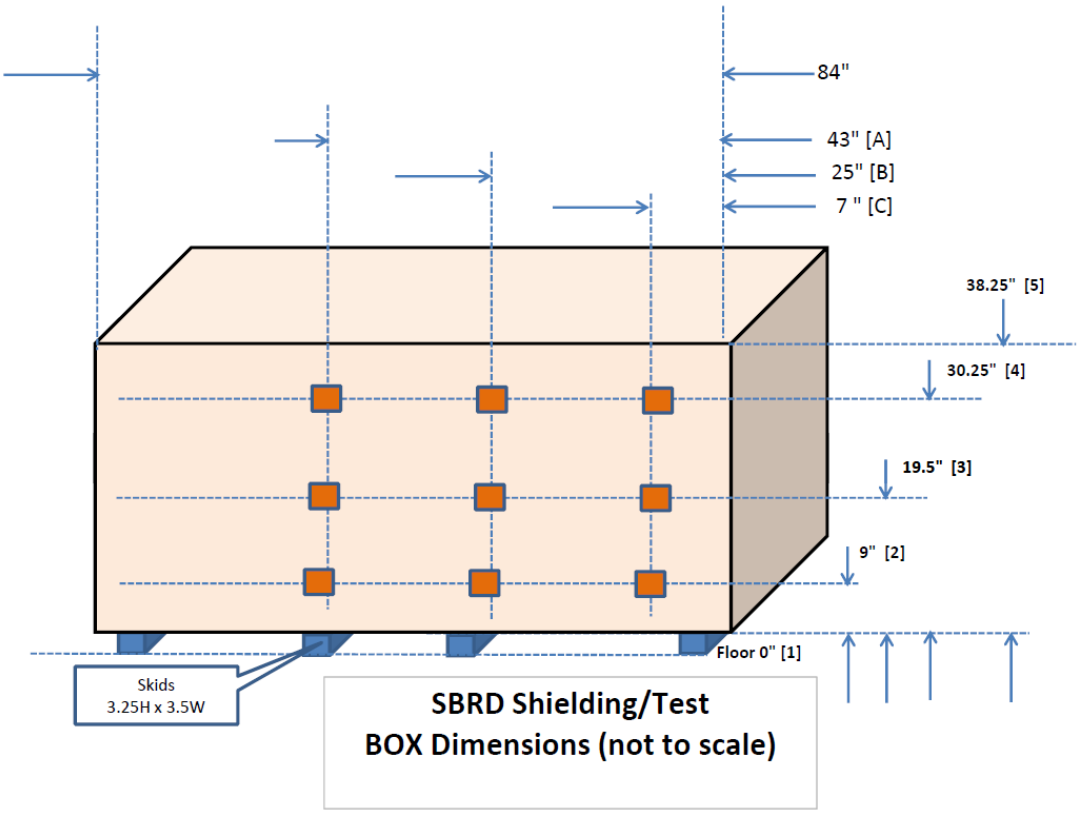


Figure 7 Shield Block Dimensions

7 MEASUREMENT PROCEDURES

A series of data sheets were developed to record the collected data on. See Appendix A. The data sheets were correlated to the SBRD system using time stamps provided by Genie 2000. Each of the test configurations and moves took several minutes to perform and each is a dedicated test with its own table or entry within a table.

A separate batch program was developed to handle some of the repetitive operations for starting a measurement and saving the spectra. The procedure on operating the batch program is provided in a separate document, "Operation of Batch Program for SBRD System Measurements."

Appendix B provides the Measurement Condition Matrix for the various experiments conducted at the TEAMS facility. A discussion of the various measurements and methodology used during the various test cases follows, with additional detail in Appendix B.

7.1 Baseline Background Radiation Measurements

Measurements of the gamma-ray background radiation were obtained without sources for the SBRD system while on the test stands, while on an empty container and for the case of a container with cargo. These measurements provide a baseline for the SBRD system response to background radiation and an indication of the cargo container's effect on the measured background radiation. 10-minute background measurements were recorded with the SBRD engaged with each container size. Background measurements were recorded at least three times each day throughout the experiment such that daily variations in background can be observed. One measurement was recorded immediately after completing startup, one was recorded at midday during a lunch break, and the final background measurement was recorded at the end of the day. Background measurements were also recorded after each change of test configuration. Spectra were recorded and saved using Genie 2000 and a batch program supplied to work in conjunction with Genie 2000. Appendix B contains the directory naming convention for the background radiation tests.

Folders with a **–G**- in the name indicate spectra with no container present. Files with a **–N**- in the name indicate spectra with empty container present. Folders with a **–P**- in the name indicate spectra with plywood shield blocks inside of the container.

7.2 SBRD Zone Mapping Measurements

The purpose of these measurements is to map out the gamma detector response for a source located in various positions throughout the container for the SBRD system. The radiation sources were used without any shielding materials to minimize the complexity of this measurement. Only the sources provided in Table 2 were necessary for the zone mapping measurements. The data was collected using a 3 minute acquisition time to ensure good counting statistics. Appendix B, The Measurement Condition Matrix, contains details of source placement and elevation of radiation sources within the container. Two source configurations were used: Cs-137/Ba-133 (20 foot and 40 foot), and Co-57 (20 foot only). The spectra were collected for each configuration using Genie 2000 and a batch program supplied to work in conjunction with Genie 2000. A directory naming convention is included in Appendix B.

Table 2. Sources and Activities Used in Zone Mapping Measurements

Source	TEAMS ID	Serial #	Source Activity as of 20 Oct 2011 (μCi)
Co-57	09-6	IFO9-1	1.51
	09-7	IFO9-2	1.51
	09-8	IFO9-3	1.51
	09-9	IFO9-4	1.51
	09-10	IFO9-5	1.51
	09-11	IFO9-6	1.51
	09-12	IFO9-7	1.51
	09-13	IFO9-8	1.51
	09-14	IFO9-9	1.51
	09-15	IFO9-10	1.51
Total Activity			**15.10**
Cs-137	09-26	IFO6-12	9.39
Total Activity			**9.39**
Ba-133	2935	948-35-2	15.42
	2936	948-35-3	15.93
Total Activity			**31.35**

7.3 Cargo Shielding Measurements

In these measurements, the detection capability of the SBRD system was measured with the gamma sources located within simulated cargo. Simulated cargo in the form of wood material (plywood blocks) on skids was loaded into the cargo container as detailed in Appendix B (Measurement Condition Matrix).

Sources (Table 1) were introduced within the simulated cargo by means of access ports that allowed the source to be positioned within the cube of cargo. The sources were only measured in one quadrant of each container, due to symmetry of the wood blocks, container, and the SBRD system.

- The wood blocks were placed inside the container such that the edges of the blocks were approximately 15 cm from the side of the container wall.
- The measurement time was 5 minutes, to improve detectability of the gamma-ray source and good statistics.
- Four sources were used: Cs-137 (264 μCi), Ba-133 (264 μCi), Co-60 (47 μCi) and Ho-166m (41 μCi).

The spectra were collected for each configuration using Genie 2000 and a batch program supplied to work in conjunction with Genie 2000. Spectra will be saved with a directory naming convention described in Appendix B. Since we are not evaluating isotopic identification as part of this test, complex evaluation of detectability is not an objective of this test.

7.4 Energy Calibration Measurements

Energy calibration was performed on the same schedule as the background measurements. The sources used were grouped into three sets of approximately equal activity. When in the forty foot configuration, all three sets were used. The first set was placed at the midpoint of the SBRD. The other two sets were placed at approximately 10 feet in from the ends (longitudinally) of the SBRD. When in the 20 foot configuration, two sets were used. Each set was placed at approximately 5 feet in from the edge of the SBRD.

Folders with a **–G-** in the name indicate spectra with no container present. Files with a **–N-** in the name indicate spectra with empty container present. Folders with a **–P-** in the name indicate spectra with plywood shield block inside of the container.

Table 3. Sources and Activities Used in Energy Calibration Measurements

Set	Source	ID	Activity (uCi)
1	Co-60	303E01-7	1
	Co-60	303E01-40	1
	Cs-137	1F06-12	10
	Ba-133	2934	15
2	Co-60	303E01-49	1
	Co-60	303E01-56	1
	Cs-137	1F06-14	10
	Ba-133	2935	15
3	Co-60	303E01-79	1
	Co-60	303E01-5	1
	Cs-137	1F06-15	10
	Ba-133	2936	15

APPENDIX A

A.1 Data Sheets and Logs

The measurement data sheets (Table A- 1 to Table A- 15) were pre-populated with the measurement case condition matrix numbers (described in Appendix B), and were filled in during the measurement process. The primary purpose of the measurement data sheets is to provide documentation to correlate the measurement to the raw detector data files.

Table A- 1: Background Radiation Baseline Data Sheet – With 20-Foot Cargo Container Measurement Procedure Checklist

Measurement	Date	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saved Spectra ✓	Initials	Comments
B-20-P-28NOV-AM	11/28/2011	600	600	✓	GAK	Time: 10:32
B-20-P-28NOV-MD	11/28/2011	600	600	✓	RHM	Time: 11:58
B-20-P-28NOV-PM	11/28/2011	600	600	✓	SJS	Time: 16:40
B-20-P-29NOV-AM	11/29/2011	600	600	✓	RHM	Time: 09:21
B-20-P-29NOV-MD	11/29/2011	600	600	✓	RHM	Time: 12:49
B-20-P-29NOV-PM	11/29/2011	600	600	✓	RHM	Time: 16:12
B-20-P-30NOV-AM	11/30/2011	600	600	✓	RHM	Time: 09:16
B-20-P-30NOV-MD	11/30/2011	600	600	✓	RHM	Time: 11:04
B-20-P-30NOV-MD1	11/30/2011	600	600	✓	RHM	Time: 13:51
B-20-P-30NOV-PM	11/30/2011	600	600	✓	RHM	Time: 16:40
B-20-P-01DEC-AM	12/01/2011	600	600	✓	RHM	Time: 08:56 High Winds
B-20-P-01DEC-MD	12/01/2011	600	600	✓	RHM	Time: 11:30 Test suspended due to high winds
B-20-P-02DEC-AM	12/02/2011	600	600	✓	RHM	Time: 10:08 Cold Winds
B-20-P-02DEC-MD	12/02/2011	600	600	✓	SJS	Time: 12:12 Cold winds
B-20-P-06DEC-AM	12/06/2011	600	600	✓	CB	Time: 09:47
B-20-P-06DEC-MD	12/06/2011	600	600	✓	CB	Time: 11:16
B-20-P-06DEC-PM	12/06/2011	600	600	✓	SJS	Time: 15:50
B-20-P-07DEC-AM	12/07/2011	600	600	✓	CB	Time: 09:17
B-20-P-07DEC-MD	12/07/2011	600	600	✓	CB	Time: 11:01

Table A- 2: Background Radiation Baseline Data Sheet – With 40-Foot Cargo Container

Measurement	Date	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saved Spectra ✓	Initials	Comments
B-40-G-11NOV	11/11/2011	600	600	✓		
B-40-P-14NOV-AM	11/14/2011	600	600	✓		Time: 09:15
B-40-P-14NOV-MD	11/14/2011	600	600	✓	CB	Time: 11:32
B-40-P-14NOV-PM	11/14/2011	600	600	✓		Time: 16:20
B-40-P-15NOV-AM	11/15/2011	600	600	✓	CB	Time: 10:09. Detectors 7 & 16 offline
B-40-P-15NOV-AM2	11/15/2011	600	600	✓	CB	Time: 10:35. Detectors 7 & 16 offline
B-40-P-15NOV-MD	11/15/2011	600	600	✓	CB	Time: 13:49. Detectors 7 & 3 offline
B-40-P-15NOV-PM	11/15/2011	600	600	✓	CB	Time: 16:29. Detector 7 offline
B-40-P-16NOV-AM	11/16/2011	600	600	✓	CB	Time: 09:01. Detector 7 offline
B-40-P-16NOV-MD	11/16/2011	600	600	✓	CB	Time: 11:02. Detector 7 offline
B-40-P-16NOV-MD2	11/16/2011	600	600	✓	CB	Time: 13:58. Detector 7 offline
B-40-P-16NOV-PM	11/16/2011	600	600	✓	CB	Time: 16:09. Detector 7 offline
B-40-P-17NOV-AM	11/17/2011	600	600	✓	CB	Time: 09:02. Detector 7 offline
B-40-P-17NOV-MD	11/17/2011	600	600	✓	CB	Time: 10:58. Detector 7 offline
B-40-P-17NOV-MD(B)	11/17/2011	600	600	✓	SJS	Time: 13:50. Detector 7 offline
B-40-P-17NOV-PM	11/17/2011	600	600	✓	RHM	Time: 16:13. Detector 7 offline
B-40-P-18NOV-AM	11/18/2011	600	600	✓	RHM	Time: 08:27. Detector 7 offline
B-40-P-18NOV-MD	11/18/2011	600	600	✓	RHM	Time: 11:50. Detector 7 offline
B-40-P-18NOV-PM	11/18/2011	600	600	✓	SJS	Time: 14:48. Detector 7 offline

Table A- 3: Energy Calibration Data Sheet – With 20-Foot Cargo Container

Measurement	Date	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saved Spectra ✓	Initials	Comments
E-20-P-28NOV-AM	11/28/2011	300	300	✓	GAK	Time: 11:04
E-20-P-28NOV-MD	11/28/2011	300	300	✓	RHM	Time: 13:39
E-20-P-28NOV-PM	11/28/2011	300	300	✓	SJS	Time: 16:28
E-20-P-29NOV-AM	11/29/2011	300	300	✓	RHM	Time: 09:37
E-20-P-29NOV-MD	11/29/2011	300	300	✓	RHM	Time: 13:05
E-20-P-29NOV-PM	11/29/2011	300	300	✓	RHM	Time: 16:26
E-20-P-30NOV-AM	11/30/2011	300	300	✓	RHM	Time: 09:34
E-20-P-30NOV-MD	11/30/2011	300	300	✓	RHM	Time: 11:18
E-20-P-30NOV-MD1	11/30/2011	300	300	✓	RHM	Time: 14:02
E-20-P-30NOV-PM	11/30/2011	300	300	✓	RHM	Time: 16:31
E-20-P-01DEC-AM	12/01/2011	300	300	✓	RHM	Time: 09:24
E-20-P-01DEC-MD	12/01/2011	300	300	✓	RHM	Time: 11:46
E-20-P-02DEC-AM	12/02/2011	300	300	✓	RHM	Time: 09:55
E-20-P-02DEC-MD	12/02/2011	300	300	✓	SJS	Time: 12:25

Table A- 4: Energy Calibration Data Sheet – With 40-Foot Cargo Container

Measurement	Date	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saved Spectra ✓	Initials	Comments
E-40-P-14NOV-AM	11/14/2011	300	300	✓		Time: 10:05
E-40-P-14NOV-MD	11/14/2011	300	300	✓	CB	Time: 11:48
E-40-P-14NOV-PM	11/14/2011	300	300	✓		Time: 16:10
E-40-P-15NOV-MD	11/15/2011	300	300	✓	CB	Time: 14:06. Detector 7 offline
E-40-P-15NOV-PM	11/15/2011	300	300	✓	CB	Time: 16:43. Detector 7 offline
E-40-P-16NOV-AM	11/16/2011	300	300	✓	CB	Time: 09:20. Detector 7 offline
E-40-P-16NOV-MD	11/16/2011	300	300	✓	CB	Time: 11:17. Detector 7 offline
E-40-P-16NOV-MD2	11/16/2011	300	300	✓	CB	Time: 16:13. Detector 7 offline
E-40-P-16NOV-PM	11/16/2011	300	300	✓	CB	Time: 16:23. Detector 7 offline
E-40-P-17NOV-AM	11/17/2011	300	300	✓	CB	Time: 09:20. Detector 7 offline
E-40-P-17NOV-MD	11/17/2011	300	300	✓	CB	Time: 11:12. Detector 7 offline
E-40-P-17NOV-MD(B)	11/17/2011	300	300	✓	RHM	Time: 14:05. Detector 7 offline
E-40-P-17NOV-PM	11/17/2011	300	300	✓	RHM	Time: 16:28. Detector 7 offline
E-40-P-18NOV-AM	11/18/2011	300	300	✓	RHM	Time: 09:48. Detector 7 offline
E-40-P-18NOV-MD	11/18/2011	300	300	✓	SJS	Time: 12:27. Detector 7 offline
E-40-P-18NOV-PM	11/18/2011	300	300	✓	SJS	Time: 15:22. Detector 7 offline

Table A- 5: Detection Zone Mapping Data Sheet – 20-Foot Cargo Container with Co-57

Date(s) of Measurements: 12/06/2011				Source(s) Used: Co-57, ID 09-6 through 09-15		
Measurement	**Source Position (cm)**			**Detector Live Time (sec)**	**Verify Saved Spectra** ✓	**Comments**
	x	**y**	**z**			
Z-20-Co-1	-264	-86	0	180	✓	
Z-20-Co-2	-264	0	0	180	✓	
Z-20-Co-3	-264	86	0	180	✓	
Z-20-Co-4	-132	-86	0	180	✓	
Z-20-Co-5	-132	0	0	180	✓	
Z-20-Co-6	-132	86	0	180	✓	
Z-20-Co-7	0	-86	0	180	✓	
Z-20-Co-8	0	0	0	180	✓	
Z-20-Co-9	0	86	0	180	✓	
Z-20-Co-10	132	-86	0	180	✓	
Z-20-Co-11	132	0	0	180	✓	
Z-20-Co-12	132	86	0	180	✓	
Z-20-Co-13	264	-86	0	180	✓	
Z-20-Co-14	264	0	0	180	✓	
Z-20-Co-15	264	86	0	180	✓	
Z-20-Co-16	-264	-86	130	180	✓	
Z-20-Co-17	-264	0	130	180	✓	
Z-20-Co-18	-264	86	130	180	✓	
Z-20-Co-19	-132	-86	130	180	✓	
Z-20-Co-20	-132	0	130	180	✓	
Z-20-Co-21	-132	86	130	180	✓	
Z-20-Co-22	0	-86	130	180	✓	
Z-20-Co-23	0	0	130	180	✓	
Z-20-Co-24	0	86	130	180	✓	
Z-20-Co-25	132	-86	130	180	✓	
Z-20-Co-26	132	0	130	180	✓	
Z-20-Co-27	132	86	130	180	✓	
Z-20-Co-28	264	-86	130	180	✓	
Z-20-Co-29	264	0	130	180	✓	
Z-20-Co-30	264	86	130	180	✓	

Table A- 6: Detection Zone Mapping Data Sheet – 20-Foot Cargo Container with Ba-133 and Cs-137

Date(s) of Measurements: 12/07/2011				Source(s) Used: Cs-137: 09-26; Ba-133: 2935 & 2936		
Measurement	**Source Position (cm)**			**Detector Live Time (sec)**	**Verify Saved Spectra** ✓	**Comments**
	x	**Y**	**z**			
Z-20-BaCs-1	-264	-86	0	180	✓	
Z-20-BaCs-2	-264	0	0	180	✓	
Z-20-BaCs-3	-264	86	0	180	✓	
Z-20- BaCs-4	-132	-86	0	180	✓	
Z-20-BaCs-5	-132	0	0	180	✓	
Z-20-BaCs-6	-132	86	0	180	✓	
Z-20-BaCs-7	0	-86	0	180	✓	
Z-20-BaCs-8	0	0	0	180	✓	
Z-20-BaCs-9	0	86	0	180	✓	
Z-20-BaCs-10	132	-86	0	180	✓	
Z-20-BaCs-11	132	0	0	180	✓	
Z-20-BaCs-12	132	86	0	180	✓	
Z-20-BaCs-13	264	-86	0	180	✓	
Z-20-BaCs-14	264	0	0	180	✓	
Z-20-BaCs-15	264	86	0	180	✓	
Z-20-BaCs-16	-264	-86	130	180	✓	
Z-20-BaCs-17	-264	0	130	180	✓	
Z-20-BaCs-18	-264	86	130	180	✓	
Z-20-BaCs-19	-132	-86	130	180	✓	
Z-20-BaCs-20	-132	0	130	180	✓	
Z-20-BaCs-21	-132	86	130	180	✓	
Z-20-BaCs-22	0	-86	130	180	✓	
Z-20-BaCs-23	0	0	130	180	✓	
Z-20-BaCs-24	0	86	130	180	✓	
Z-20-BaCs-25	132	-86	130	180	✓	
Z-20-BaCs-26	132	0	130	180	✓	
Z-20-BaCs-27	132	86	130	180	✓	
Z-20-BaCs-28	264	-86	130	180	✓	
Z-20-BaCs-29	264	0	130	180	✓	
Z-20-BaCs-30	264	86	130	180	✓	

Table A- 7: Detection Zone Mapping Data Sheet – 40-Foot Cargo Container with Ba-133 and Cs-137

Date(s) of Measurements: 11/03/2011				Source(s) Used: Cs-137: 09-26; Ba-133: 2935 and 2936		
Measurement	**Source Position (cm)**			**Detector Live Time (sec)**	**Verify Saved Spectra** ✓	**Comments**
	x	**Y**	**z**			
Z-40-BaCs-1	-570	-86	0	120	✓	
Z-40-BaCs-2	-570	0	0	120	✓	
Z-40-BaCs-3	-570	86	0	120	✓	
Z-40-BaCs-4	-285	-86	0	120	✓	
Z-40-BaCs-5	-285	0	0	120	✓	
Z-40-BaCs-6	-285	86	0	120	✓	
Z-40-BaCs-7	0	-86	0	120	✓	
Z-40-BaCs-8	0	0	0	120	✓	
Z-40-BaCs-9	0	86	0	120	✓	
Z-40-BaCs-10	285	-86	0	120	✓	
Z-40-BaCs-11	285	0	0	120	✓	
Z-40-BaCs-12	285	86	0	120	✓	
Z-40-BaCs-13	570	-86	0	120	✓	
Z-40-BaCs-14	570	0	0	120	✓	
Z-40-BaCs-15	570	86	0	120	✓	
Z-40-BaCs-16	-570	-86	130	120	✓	
Z-40-BaCs-17	-570	0	130	120	✓	
Z-40-BaCs-18	-570	86	130	120	✓	
Z-40-BaCs-19	-285	-86	130	120	✓	
Z-40-BaCs-20	-285	0	130	120	✓	
Z-40-BaCs-21	-285	86	130	120	✓	
Z-40-BaCs-22	0	-86	130	120	✓	
Z-40-BaCs-23	0	0	130	120	✓	
Z-40-BaCs-24	0	86	130	120	✓	
Z-40-BaCs-25	285	-86	130	120	✓	
Z-40-BaCs-26	285	0	130	120	✓	
Z-40-BaCs-27	285	86	130	120	✓	
Z-40-BaCs-28	570	-86	130	120	✓	
Z-40-BaCs-29	570	0	130	120	✓	
Z-40-BaCs-30	570	86	130	120	✓	

Table A- 8: Cargo Shielding Measurement Data Sheet – for 20-Foot Container Using Cs-137

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-20-Cs-0	-290	A	5		11:14	300	300	✓	11/28/2011
C-20-Cs-1	-290	A	4		11:22	300	300	✓	11/28/2011
C-20-Cs-2	-290	A	3		11:31	300	300	✓	11/28/2011
C-20-Cs-3	-290	A	2		11:41	300	300	✓	11/28/2011
C-20-Cs-4	-290	A	1		11:48	300	300	✓	11/28/2011
C-20-Cs-5	-290	C	4		13:48	300	300	✓	11/28/2011
C-20-Cs-6	-290	C	3		13:55	300	300	✓	11/28/2011
C-20-Cs-7	-290	C	2		14:02	300	300	✓	11/28/2011
C-20-Cs-8	-290	C	1		14:11	300	300	✓	11/28/2011
C-20-Cs-9	-168	A	4		14:18	300	300	✓	11/28/2011
C-20-Cs-10	-168	A	3		14:26	300	300	✓	11/28/2011
C-20-Cs-11	-168	A	2		14:33	300	300	✓	11/28/2011
C-20-Cs-12	-168	A	1		14:41	300	300	✓	11/28/2011
C-20-Cs-13	-168	C	4		14:49	300	300	✓	11/28/2011
C-20-Cs-14	-168	C	3		14:56	300	300	✓	11/28/2011
C-20-Cs-15	-168	C	2		15:03	300	300	✓	11/28/2011
C-20-Cs-16	-168	C	1		15:10	300	300	✓	11/28/2011
C-20-Cs-17	0	A	4		15:20	300	300	✓	11/30/2011
C-20-Cs-18	0	A	3		15:29	300	300	✓	11/30/2011
C-20-Cs-19	0	A	2		15:35	300	300	✓	11/30/2011
C-20-Cs-20	0	A	1		15:49	300	300	✓	11/30/2011
C-20-Cs-21	0	C	4		15:58	300	300	✓	11/30/2011
C-20-Cs-22	0	C	3		16:06	300	300	✓	11/30/2011
C-20-Cs-23	0	C	2		16:15	300	300	✓	11/30/2011
C-20-Cs-24	0	C	1		16:22	300	300	✓	11/30/2011
Source: Cs-137 ID# RS870								**Date:** 11/28/2011 & 11/30/2011	

Table A- 9: Cargo Shielding Measurement Data Sheet – for 20-Foot Container Using Ba-133

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-20-Ba-0	-290	A	5		15:19	300	300	✓	11/28/2011
C-20-Ba-1	-290	A	4		15:27	300	300	✓	11/28/2011
C-20-Ba-2	-290	A	3		15:34	300	300	✓	11/28/2011
C-20-Ba-3	-290	A	2		15:42	300	300	✓	11/28/2011
C-20-Ba-4	-290	A	1		15:49	300	300	✓	11/28/2011
C-20-Ba-5	-290	C	4		15:57	300	300	✓	11/28/2011
C-20-Ba-6	-290	C	3		16:04	300	300	✓	11/28/2011
C-20-Ba-7	-290	C	2		16:11	300	300	✓	11/28/2011
C-20-Ba-8	-290	C	1		16:20	300	300	✓	11/28/2011
C-20-Ba-9	-168	A	4		09:49	300	300	✓	11/29/2011
C-20-Ba-10	-168	A	3		09:55	300	300	✓	11/29/2011
C-20-Ba-11	-168	A	2		10:03	300	300	✓	11/29/2011
C-20-Ba-12	-168	A	1		10:11	300	300	✓	11/29/2011
C-20-Ba-13	-168	C	4		10:19	300	300	✓	11/29/2011
C-20-Ba-14	-168	C	3		10:26	300	300	✓	11/29/2011
C-20-Ba-15	-168	C	2		10:33	300	300	✓	11/29/2011
C-20-Ba-16	-168	C	1		14:04	300	300	✓	11/29/2011
C-20-Ba-17	0	A	4		09:36	300	300	✓	12/01/2011
C-20-Ba-18	0	A	3		09:45	300	300	✓	12/01/2011
C-20-Ba-19	0	A	2		09:54	300	300	✓	12/01/2011
C-20-Ba-20	0	A	1		10:04	300	300	✓	12/01/2011
C-20-Ba-21	0	C	4		10:13	300	300	✓	12/01/2011
C-20-Ba-22	0	C	3		10:21	300	300	✓	12/01/2011
C-20-Ba-23	0	C	2		10:29	300	300	✓	12/01/2011
C-20-Ba-24	0	C	1		10:38	300	300	✓	12/01/2011
Source: BA-133 ID# RS1616								**Date: 11/28/2011,11/29/2011 & 12/01/2011**	

Table A- 10: Cargo Shielding Measurement Data Sheet – for 20-Foot Container Using Co-60

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-20-Co60-0	-290	A	5		14:01	300	300	✓	11/29/2011
C-20-Co60-1	-290	A	4		14:20	300	300	✓	11/29/2011
C-20- Co60-2	-290	A	3		14:27	300	300	✓	11/29/2011
C-20- Co60-3	-290	A	2		14:34	300	300	✓	11/29/2011
C-20- Co60-4	-290	A	1		15:47	300	300	✓	11/29/2011
C-20- Co60-5	-290	C	4		15;56	300	300	✓	11/29/2011
C-20- Co60-6	-290	C	3		16:03	300	300	✓	11/29/2011
C-20- Co60-7	-290	C	2		09:43	300	300	✓	11/30/2011
C-20- Co60-8	-290	C	1		09:51	300	300	✓	11/30/2011
C-20- Co60-9	-168	A	4		10:00	300	300	✓	11/30/2011
C-20- Co60-10	-168	A	3		10:08	300	300	✓	11/30/2011
C-20- Co60-11	-168	A	2		10:15	300	300	✓	11/30/2011
C-20- Co60-12	-168	A	1		10:23	300	300	✓	11/30/2011
C-20- Co60-13	-168	C	4		10:30	300	300	✓	11/30/2011
C-20- Co60-14	-168	C	3		10:39	300	300	✓	11/30/2011
C-20- Co60-15	-168	C	2		10:49	300	300	✓	11/30/2011
C-20- Co60-16	-168	C	1		10:56	300	300	✓	11/30/2011
C-20- Co60-17	0	A	4		10:48	300	300	✓	12/01/2011, High winds
C-20- Co60-18	0	A	3		10:56	300	300	✓	12/01/2011, High winds
C-20- Co60-19	0	A	2		11:04	300	300	✓	12/01/2011, High winds
C-20- Co60-20	0	A	1		11:15	300	300	✓	12/01/2011, High winds
C-20- Co60-21	0	C	4		11:20	300	300	✓	12/01/2011, High winds
C-20- Co60-22	0	C	3		10:29	300	300	✓	12/02/2011, Cold winds
C-20- Co60-23	0	C	2		10:38	300	300	✓	12/02/2011, Cold winds
C-20- Co60-24	0	C	1		10:43	300	300	✓	12/02/2011, Cold winds
Source: Co-60 ID# RS1149								**Date**	

Table A- 11: Cargo Shielding Measurement Data Sheet – for 20-Foot Container Using Ho-166m

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-20-Ho-1	0	A	5		10:55	300	300	✓	12/02/2011, Cold winds
C-20-Ho-2	0	C	5		11:02	300	300	✓	12/02/2011, Cold winds
C-20-Ho-3	0	A	4		11:10	300	300	✓	12/02/2011, Cold winds
C-20-Ho-4	0	A	3		11:16	300	300	✓	12/02/2011, Cold winds
C-20-Ho-5	0	A	2		11:23	300	300	✓	12/02/2011, Cold winds
C-20-Ho-6	0	A	1		11:30	300	300	✓	12/02/2011, Cold winds
C-20-Ho-7	0	C	4		11:38	300	300	✓	12/02/2011, Cold winds
C-20-Ho-8	0	C	3		11:45	300	300	✓	12/02/2011, Cold winds
C-20-Ho-9	0	C	2		11:52	300	300	✓	12/02/2011, Cold winds
C-20-Ho-10	0	C	1		12:01	300	300	✓	12/02/2011, Cold winds
Source: Ho-166m ID# RS887								**Date**	

Note: On Top for Shield Row means the source will be placed on top of the cargo shield.

Table A- 12: Cargo Shielding Measurement Data Sheet – for 40-Foot Container Using Cs-137

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Cs-0	-596	A	5		10:20	300	300	✓	11/14/2011
C-40-Cs-1	-596	A	4		10:27	300	300	✓	11/14/2011
C-40-Cs-2	-596	A	3		10:38	300	300	✓	11/14/2011
C-40-Cs-3	-596	A	2		10:47	300	300	✓	11/14/2011
C-40-Cs-4	-596	A	1		10:56	300	300	✓	11/14/2011
C-40-Cs-5	-596	C	4		11:05	300	300	✓	11/14/2011
C-40-Cs-6	-596	C	3		11:14	300	300	✓	11/14/2011
C-40-Cs-7	-596	C	2		11:24	300	300	✓	11/14/2011
C-40-Cs-8	-596	C	1		13:22	300	300	✓	11/14/2011
C-40-Cs-9	-474	A	4		13:35	300	300	✓	11/14/2011
C-40-Cs-10	-474	A	3		13:43	300	300	✓	11/14/2011
C-40-Cs-11	-474	A	2		13:51	300	300	✓	11/14/2011
C-40-Cs-12	-474	A	1		14:04	300	300	✓	11/14/2011
C-40-Cs-13	-474	C	4		14:13	300	300	✓	11/14/2011
C-40-Cs-14	-474	C	3		14:22	300	300	✓	11/14/2011
C-40-Cs-15	-474	C	2		14:32	300	300	✓	11/14/2011
C-40-Cs-16	-474	C	1		14:40	300	300	✓	11/14/2011
C-40-Cs-17	-244	A	4		14:25	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-18	-244	A	3		14:33	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-19	-244	A	2		14:41	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-20	-244	A	1		14:49	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-21	-244	C	4		14:57	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-22	-244	C	3		15:05	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-23	-244	C	2		15:13	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-24	-244	C	1		15:20	300	300	✓	11/16/2011, Detector 7 offline
C-40-Cs-25	0	A	4		14:15	300	300	✓	11/17/2011, Detector 7 offline
C-40-Cs-26	0	A	3		14:22	300	300	✓	11/17/2011, Detector 7 offline
C-40-Cs-27	0	A	2		14:32	300	300	✓	11/17/2011, Detector 7 offline
C-40-Cs-28	0	A	1		14:40	300	300	✓	11/17/2011, Detector 7 offline
C-40-Cs-29	0	C	4		14:50	300	300	✓	11/17/2011, Detector 7 offline
C-40-Cs-30	0	C	3		15:01	300	300	✓	11/17/2011, Detector 7 offline

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Cs-31	0	C	2		15:09	300	300	✓	11/17/2011, Detector 7 offline
C-40-Cs-32	0	C	1		15:17	300	300	✓	11/17/2011, Detector 7 offline
Source: Cs-137 ID# RS870								**Date**	

Table A- 13: Cargo Shielding Measurement Data Sheet – for 40-Foot Container Using Ba-133

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Ba-0	-596	A	5		14:48	300	300	✓	11/14/2011
C-40-Ba-1	-596	A	4		14:58	300	300	✓	11/14/2011
C-40-Ba-2	-596	A	3		15:05	300	300	✓	11/14/2011
C-40-Ba-3	-596	A	2		15:13	300	300	✓	11/14/2011
C-40-Ba-4	-596	A	1		15:21	300	300	✓	11/14/2011
C-40-Ba-5	-596	C	4		15:28	300	300	✓	11/14/2011
C-40-Ba-6	-596	C	3		15:37	300	300	✓	11/14/2011
C-40-Ba-7	-596	C	2		15:43	300	300	✓	11/14/2011
C-40-Ba-8	-596	C	1		15:50	300	300	✓	11/14/2011
C-40-Ba-9	-474	A	4		15:59	300	300	✓	11/14/2011
C-40-Ba-10	-474	A	3		14:21	300	300	✓	11/15/2011
C-40-Ba-11	-474	A	2		14:29	300	300	✓	11/15/2011
C-40-Ba-12	-474	A	1		14:39	300	300	✓	11/15/2011
C-40-Ba-13	-474	C	4		14:49	300	300	✓	11/15/2011
C-40-Ba-14	-474	C	3		14:58	300	300	✓	11/15/2011
C-40-Ba-15	-474	C	2		15:06	300	300	✓	11/15/2011
C-40-Ba-16	-474	C	1		15:15	300	300	✓	11/15/2011
C-40-Ba-17	-244	A	4		15:30	300	300	✓	11/16/2011
C-40-Ba-18	-244	A	3		15:38	300	300	✓	11/16/2011
C-40-Ba-19	-244	A	2		15:45	300	300	✓	11/16/2011
C-40-Ba-20	-244	A	1		15:53	300	300	✓	11/16/2011
C-40-Ba-21	-244	C	4		16:01	300	300	✓	11/16/2011
C-40-Ba-22	-244	C	3		09:30	300	300	✓	11/17/2011
C-40-Ba-23	-244	C	2		09:37	300	300	✓	11/17/2011
C-40-Ba-24	-244	C	1		09:45	300	300	✓	11/17/2011
C-40-Ba-25	0	A	4		13:33	300	300	✓	11/18/2011
C-40-Ba-26	0	A	3		13:43	300	300	✓	11/18/2011
C-40-Ba-27	0	A	2		13:52	300	300	✓	11/18/2011
C-40-Ba-28	0	A	1		14:01	300	300	✓	11/18/2011
C-40-Ba-29	0	C	4		14:11	300	300	✓	11/18/2011
C-40-Ba-30	0	C	3		14:21	300	300	✓	11/18/2011

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Ba-31	0	C	2		14:30	300	300	✓	11/18/2011
C-40-Ba-32	0	C	1		14:38	300	300	✓	11/18/2011
Source: Ba-133 ID# RS1616								**Date**	

Table A- 14: Cargo Shielding Measurement Data Sheet – for 40-Foot Container Using Co-60

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Co60-0	-596	A	5		15:26	300	300	✓	11/15/2011, Detector 7 offline
C-40-Co60-1	-596	A	4		15:34	300	300	✓	11/15/2011, Detector 7 offline
C-40-Co60-2	-596	A	3		15:43	300	300	✓	11/15/2011, Detector 7 offline
C-40-Co60-3	-596	A	2		15:50	300	300	✓	11/15/2011, Detector 7 offline
C-40-Co60-4	-596	A	1		15:59	300	300	✓	11/15/2011, Detector 7 offline
C-40-Co60-5	-596	C	4		16:09	300	300	✓	11/15/2011, Detector 7 offline
C-40-Co60-6	-596	C	3		09:31	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-7	-596	C	2		09:38	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-8	-596	C	1		09:46	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-9	-474	A	4		09:56	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-10	-474	A	3		10:04	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-11	-474	A	2		10:12	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-12	-474	A	1		10:21	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-13	-474	C	4		10:29	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-14	-474	C	3		10:37	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-15	-474	C	2		10:44	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-16	-474	C	1		10:54	300	300	✓	11/16/2011, Detector 7 offline
C-40-Co60-17	-244	A	4		09:55	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-18	-244	A	3		10:02	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-19	-244	A	2		10:10	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-20	-244	A	1		10:18	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-21	-244	C	4		10:26	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-22	-244	C	3		10:34	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-23	-244	C	2		10:42	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-24	-244	C	1		10:50	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-25	0	A	4		15:27	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-26	0	A	3		15:35	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-27	0	A	2		15:52	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-28	0	A	1		16:01	300	300	✓	11/17/2011, Detector 7 offline
C-40-Co60-29	0	C	4		10:00	300	300	✓	11/18/2011, Detector 7 offline
C-40-Co60-30	0	C	3		10:16	300	300	✓	11/18/2011, Detector 7 offline

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Co60-31	0	C	2		10:26	300	300	✓	11/18/2011, Detector 7 offline
C-40-Co60-32	0	C	1		10:38	300	300	✓	11/18/2011, Detector 7 offline
Source: Co-60 ID# RS1149								**Date**	

Table A- 15: Cargo Shielding Measurement Data Sheet – for 40-Foot Container Using Ho-166m

Measurement	Source Position (cm)			Omit ✓	Start Time	Planned Live Time (sec)	Actual Live Time (sec)	Verify Saving of Spectra ✓	Comments
	Length Position	Shield Column	Shield Row						
C-40-Ho-1	0	A	5		11:12	300	300		11/18/2011, Detector 7 offline
C-40-Ho-2	0	C	5		11:23	300	300		11/18/2011, Detector 7 offline
C-40-Ho-3	0	A	4		11:36	300	300		11/18/2011, Detector 7 offline
C-40-Ho-4	0	A	3		11:45	300	300		11/18/2011, Detector 7 offline
C-40-Ho-5	0	A	2		12:35	300	300		11/18/2011, Detector 7 offline
C-40-Ho-6	0	A	1		12:44	300	300		11/18/2011, Detector 7 offline
C-40-Ho-7	0	C	4		12:52	300	300		11/18/2011, Detector 7 offline
C-40-Ho-8	0	C	3		1300	300	300		11/18/2011, Detector 7 offline
C-40-Ho-9	0	C	2		13:11	300	300		11/18/2011, Detector 7 offline
C-40-Ho-10	0	C	1		13:23	300	300		11/18/2011, Detector 7 offline
Source: Ho-166m ID# RS887								**Date**	

Note: On Top for Shield Row means the source will be placed on top of the cargo shield.

APPENDIX B

B.1 Measurement Conditions

In order to meet the objectives of this data collection, several different configurations of radiation sources were executed using the measurement procedures of Section 7. These configurations take into account the various possible locations of a source within a cargo container, the different container sizes, and gamma radiation sources. Gamma sources of different energies were tested to map out the response of the system to radiation. Several configurations of sources, their location within the shipping container, and shielding material used between the sources and detectors were tested. There are three major measurements: background radiation sampling, the SBRD zone mapping, and cargo shielding. The various experimental configurations for each of these measurement cases are documented in the following subsections.

B.1.1 Data File Format

Data was saved in both Canberra .CNF and Canberra .IEC formats.

B.1.2 Directory/File Naming Convention

For all tests, each measurement has a unique identifier code. This identifier is also used as the directory under which all spectrum files for the 32 detectors for the 40-foot configuration and 20 detectors for the 20 foot configuration were placed. Combined with the unique identifier for the detector, this directory/file structure will allow one to easily view specific files for detector responses from specific tests and measurements. The table below shows the directory naming structure for the measurements

Table B.1: Directory and Experimental Configuration Naming Convention for TEAMS Measurements

Background Radiation Sampling (B)	B-container size-shielding-DDMMM-time
Definition: background-container size (20 or 40)-shielding (none-N, plywood-P, fiberboard-F)-date(day and month)-time (morning-AM, midday (MD), afternoon (PM))	
Energy Calibration (E)	E-DDMMM-time
Definition: energy calibration-date (day and month)-time (military time)	
Zone Mapping Measurements (Z)	Z-container size-source-#
Definition: zone mapping-container size (20 or 40)-radioisotope source-measurement number	
Cargo Shielding Measurements (C)	C-container size-source-#
Definition: cargo shielding-container size (20 or 40)-radioisotope source- measurement number	
Other Measurements	O-container size-shielding-source-#
Definition: other- container size (20 or 40)- shielding (none-N, plywood-P, fiberboard-F)-radioisotope source- measurement number	

B.2 Background Radiation Sampling Measurement Conditions

Background measurements were made three times per day and after a change in cargo configuration in accordance with the plan described in Section 7.1. A background measurement for each empty container was also made. All background measurements were a minimum of 10 minutes (live time).

B.3 Energy Calibration Measurements

Energy calibration measurements were made 3 times each day in accordance with the plan described in Section 7.4. Energy calibration measurements were a minimum of 5 minutes (live time).

B.3 Zone Mapping Measurements

For the detection zone mapping, the full container floor area was mapped out. When entering the container, the bottom right hand corner of the door (when facing into the container from the door) is the start of the coordinate system with the x-axis parallel to the container length (along the container toward the far wall), the y-axis parallel across the width of the container (along the door), and the z-axis in the vertical direction (see Figure B.1). The source locations were mapped out and provide symmetric locations within the cargo container. Two elevations of measurements were performed during the zone mapping measurements for each container size: one on the floor of the container (assumed to be z=0 cm) and one at the mid-height of the container (approximately 130 cm). Tables B.3 through B.6 contain the Measurement Matrices for zone mapping the all sources and containers.

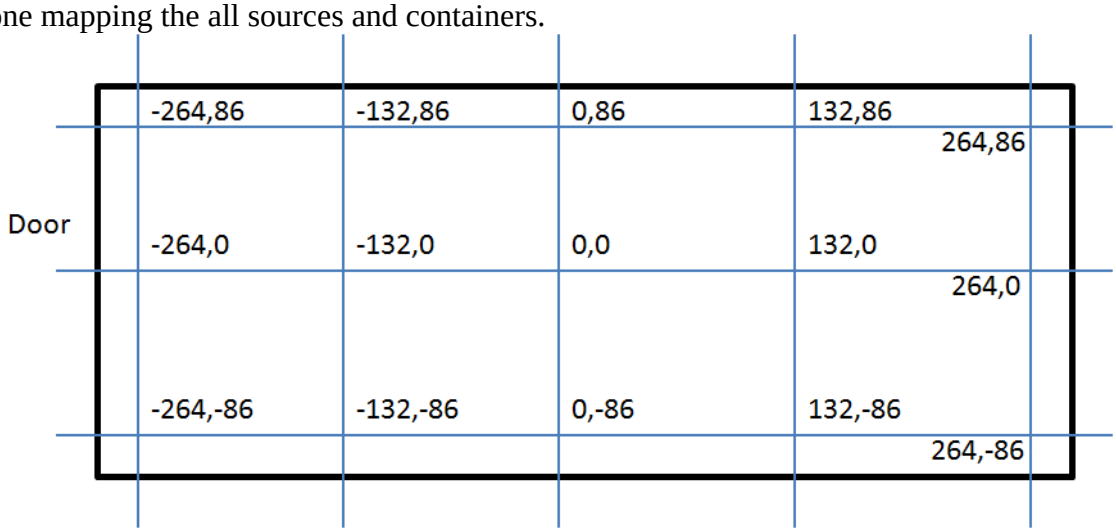


Figure B.1. Floor map locations for the sources used in the zone-mapping experiment (coordinates for the 20 foot container measurements are shown). In addition, two heights of measurements were recorded in each container.

Table B.2: Zone Mapping Measurement Condition Matrix for 20-Foot Container Using Co-57

Measurement	Container length	Source Position (cm)		
		x	y	Z
Z-20-Co-1	20	-264	-86	0
Z-20-Co-2	20	-264	0	0
Z-20-Co-3	20	-264	86	0
Z-20-Co-4	20	-132	-86	0
Z-20-Co-5	20	-132	0	0
Z-20-Co-6	20	-132	86	0
Z-20-Co-7	20	0	-86	0
Z-20-Co-8	20	0	0	0
Z-20-Co-9	20	0	86	0
Z-20-Co-10	20	132	-86	0
Z-20-Co-11	20	132	0	0
Z-20-Co-12	20	132	86	0
Z-20-Co-13	20	264	-86	0
Z-20-Co-14	20	264	0	0
Z-20-Co-15	20	264	86	0
Z-20-Co-16	20	-264	-86	130
Z-20-Co-17	20	-264	0	130
Z-20-Co-18	20	-264	86	130
Z-20-Co-19	20	-132	-86	130
Z-20-Co-20	20	-132	0	130
Z-20-Co-21	20	-132	86	130
Z-20-Co-22	20	0	-86	130
Z-20-Co-23	20	0	0	130
Z-20-Co-24	20	0	86	130
Z-20-Co-25	20	132	-86	130
Z-20-Co-26	20	132	0	130
Z-20-Co-27	20	132	86	130
Z-20-Co-28	20	264	-86	130
Z-20-Co-29	20	264	0	130
Z-20-Co-30	20	264	86	130

Table B.3: Zone Mapping Measurement Condition Matrix for 20-Foot Container Using Cs-137 and Ba-133

Measurement	Container length	Source Position (cm)		
		x	Y	z
Z-20-BaCs-1	20	-264	-86	0
Z-20-BaCs-2	20	-264	0	0
Z-20-BaCs-3	20	-264	86	0
Z-20- BaCs-4	20	-132	-86	0
Z-20-BaCs-5	20	-132	0	0
Z-20-BaCs-6	20	-132	86	0
Z-20-BaCs-7	20	0	-86	0
Z-20-BaCs-8	20	0	0	0
Z-20-BaCs-9	20	0	86	0
Z-20-BaCs-10	20	132	-86	0
Z-20-BaCs-11	20	132	0	0
Z-20-BaCs-12	20	132	86	0
Z-20-BaCs-13	20	264	-86	0
Z-20-BaCs-14	20	264	0	0
Z-20-BaCs-15	20	264	86	0
Z-20-BaCs-16	20	-264	-86	130
Z-20-BaCs-17	20	-264	0	130
Z-20-BaCs-18	20	-264	86	130
Z-20-BaCs-19	20	-132	-86	130
Z-20-BaCs-20	20	-132	0	130
Z-20-BaCs-21	20	-132	86	130
Z-20-BaCs-22	20	0	-86	130
Z-20-BaCs-23	20	0	0	130
Z-20-BaCs-24	20	0	86	130
Z-20-BaCs-25	20	132	-86	130
Z-20-BaCs-26	20	132	0	130
Z-20-BaCs-27	20	132	86	130
Z-20-BaCs-28	20	264	-86	130
Z-20-BaCs-29	20	264	0	130
Z-20-BaCs-30	20	264	86	130

Table B.4: Zone Mapping Measurement Condition Matrix for 20-Foot Container Using Co-60

Measurement	Container length	Source Position (cm)		
		x	Y	z
Z-20-Co60-1	20	-264	-86	0
Z-20-Co60-2	20	-264	0	0
Z-20-Co60-3	20	-264	86	0
Z-20-Co60-4	20	-132	-86	0
Z-20-Co60-5	20	-132	0	0
Z-20-Co60-6	20	-132	86	0
Z-20-Co60-7	20	0	-86	0
Z-20-Co60-8	20	0	0	0
Z-20-Co60-9	20	0	86	0
Z-20-Co60-10	20	132	-86	0
Z-20-Co60-11	20	132	0	0
Z-20-Co60-12	20	132	86	0
Z-20-Co60-13	20	264	-86	0
Z-20-Co60-14	20	264	0	0
Z-20-Co60-15	20	264	86	0
Z-20-Co60-16	20	-264	-86	130
Z-20-Co60-17	20	-264	0	130
Z-20-Co60-18	20	-264	86	130
Z-20-Co60-19	20	-132	-86	130
Z-20-Co60-20	20	-132	0	130
Z-20-Co60-21	20	-132	86	130
Z-20-Co60-22	20	0	-86	130
Z-20-Co60-23	20	0	0	130
Z-20-Co60-24	20	0	86	130
Z-20-Co60-25	20	132	-86	130
Z-20-Co60-26	20	132	0	130
Z-20-Co60-27	20	132	86	130
Z-20-Co60-28	20	264	-86	130
Z-20-Co60-29	20	264	0	130
Z-20-Co60-30	20	264	86	130

Table B.5: Zone Mapping Measurement Condition Matrix for 40-Foot Container Using Co-57

Measurement	Container length	Source Position (cm)		
		x	Y	z
Z-40-Co-1	40	-570	-86	0
Z-40-Co-2	40	-570	0	0
Z-40-Co-3	40	-570	86	0
Z-40-Co-4	40	-285	-86	0
Z-40-Co-5	40	-285	0	0
Z-40-Co-6	40	-285	86	0
Z-40-Co-7	40	0	-86	0
Z-40-Co-8	40	0	0	0
Z-40-Co-9	40	0	86	0
Z-40-Co-10	40	285	-86	0
Z-40-Co-11	40	285	0	0
Z-40-Co-12	40	285	86	0
Z-40-Co-13	40	570	-86	0
Z-40-Co-14	40	570	0	0
Z-40-Co-15	40	570	86	0
Z-40-Co-16	40	-570	-86	130
Z-40-Co-17	40	-570	0	130
Z-40-Co-18	40	-570	86	130
Z-40-Co-19	40	-285	-86	130
Z-40-Co-20	40	-285	0	130
Z-40-Co-21	40	-285	86	130
Z-40-Co-22	40	0	-86	130
Z-40-Co-23	40	0	0	130
Z-40-Co-24	40	0	86	130
Z-40-Co-25	40	285	-86	130
Z-40-Co-26	40	285	0	130
Z-40-Co-27	40	285	86	130
Z-40-Co-28	40	570	-86	130
Z-40-Co-29	40	570	0	130
Z-40-Co-30	40	570	86	130

Table B.6: Zone Mapping Measurement Condition Matrix for 40-Foot Container Using Cs-137 and Ba-133

Measurement	Container length	Source Position (cm)		
		x	y	z
Z-40-BaCs-1	40	-570	-86	0
Z-40-BaCs-2	40	-570	0	0
Z-40-BaCs-3	40	-570	86	0
Z-40-BaCs-4	40	-285	-86	0
Z-40-BaCs-5	40	-285	0	0
Z-40-BaCs-6	40	-285	86	0
Z-40-BaCs-7	40	0	-86	0
Z-40-BaCs-8	40	0	0	0
Z-40-BaCs-9	40	0	86	0
Z-40-BaCs-10	40	285	-86	0
Z-40-BaCs-11	40	285	0	0
Z-40-BaCs-12	40	285	86	0
Z-40-BaCs-13	40	570	-86	0
Z-40-BaCs-14	40	570	0	0
Z-40-BaCs-15	40	570	86	0
Z-40-BaCs-16	40	-570	-86	130
Z-40-BaCs-17	40	-570	0	130
Z-40-BaCs-18	40	-570	86	130
Z-40-BaCs-19	40	-285	-86	130
Z-40-BaCs-20	40	-285	0	130
Z-40-BaCs-21	40	-285	86	130
Z-40-BaCs-22	40	0	-86	130
Z-40-BaCs-23	40	0	0	130
Z-40-BaCs-24	40	0	86	130
Z-40-BaCs-25	40	285	-86	130
Z-40-BaCs-26	40	285	0	130
Z-40-BaCs-27	40	285	86	130
Z-40-BaCs-28	40	570	-86	130
Z-40-BaCs-29	40	570	0	130
Z-40-BaCs-30	40	570	86	130

Table B.7: Zone Mapping Measurement Condition Matrix for 40-Foot Container Using Co-60

Measurement	Container length	Source Position (cm)		
		x	y	z
Z-40-Co60-1	40	-570	-86	0
Z-40-Co60-2	40	-570	0	0
Z-40-Co60-3	40	-570	86	0
Z-40-Co60-4	40	-285	-86	0
Z-40-Co60-5	40	-285	0	0
Z-40-Co60-6	40	-285	86	0
Z-40-Co60-7	40	0	-86	0
Z-40-Co60-8	40	0	0	0
Z-40-Co60-9	40	0	86	0
Z-40-Co60-10	40	285	-86	0
Z-40-Co60-11	40	285	0	0
Z-40-Co60-12	40	285	86	0
Z-40-Co60-13	40	570	-86	0
Z-40-Co60-14	40	570	0	0
Z-40-Co60-15	40	570	86	0
Z-40-Co60-16	40	-570	-86	130
Z-40-Co60-17	40	-570	0	130
Z-40-Co60-18	40	-570	86	130
Z-40-Co60-19	40	-285	-86	130
Z-40-Co60-20	40	-285	0	130
Z-40-Co60-21	40	-285	86	130
Z-40-Co60-22	40	0	-86	130
Z-40-Co60-23	40	0	0	130
Z-40-Co60-24	40	0	86	130
Z-40-Co60-25	40	285	-86	130
Z-40-Co60-26	40	285	0	130
Z-40-Co60-27	40	285	86	130
Z-40-Co60-28	40	570	-86	130
Z-40-Co60-29	40	570	0	130
Z-40-Co60-30	40	570	86	130

B.4 Cargo Shielding Measurements

For the cargo shielding measurements, several source positions and shielding configurations were employed in the measurements. For the 20 foot container, measurements at three length positions in the container, using 2 shielding configurations were made. The different shielding configurations (shown in Figure B.2) were designed to provide multiple lengths at which to record data, while minimizing the number of block movements with the forklift (all length positions are relative to the centerline (C_L) of the container. Only two columns of the block access ports will be used (Column 1 and Column 3), with measurements at all four rows of ports as shown in Figure 1. Plywood blocks were used as shielding material for this phase. Tables B.7 - B.9 provide the condition matrix for the cargo shielding measurements with the 20-foot container.

For the 40-foot container, measurements were taken at four length positions in the container, using 3 shielding configurations. The different shielding configurations (shown in Figure B.3) were designed to provide multiple lengths at which to record data, while minimizing the number of block movements with the forklift. Only two columns of the block access ports were used (Column 1 and Column 3), with measurements at all four rows of ports as shown in Figure 1.

Plywood blocks were used as shielding material for this phase. Tables B.10 - B.12 provide the condition matrix for the cargo shielding measurements with the 40-foot container.

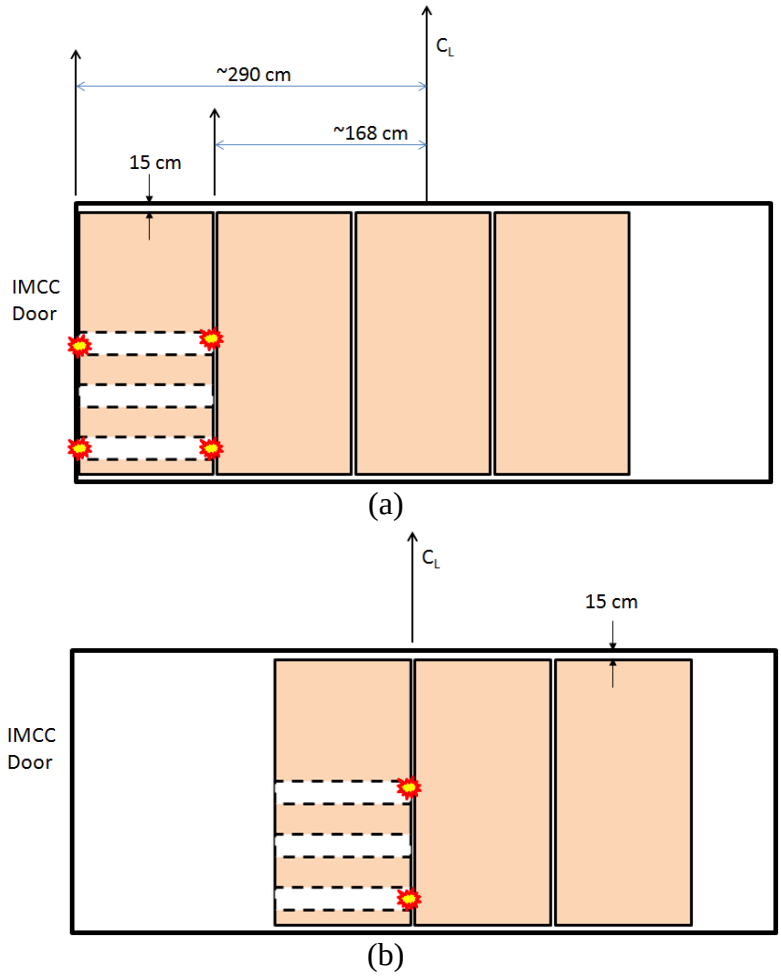
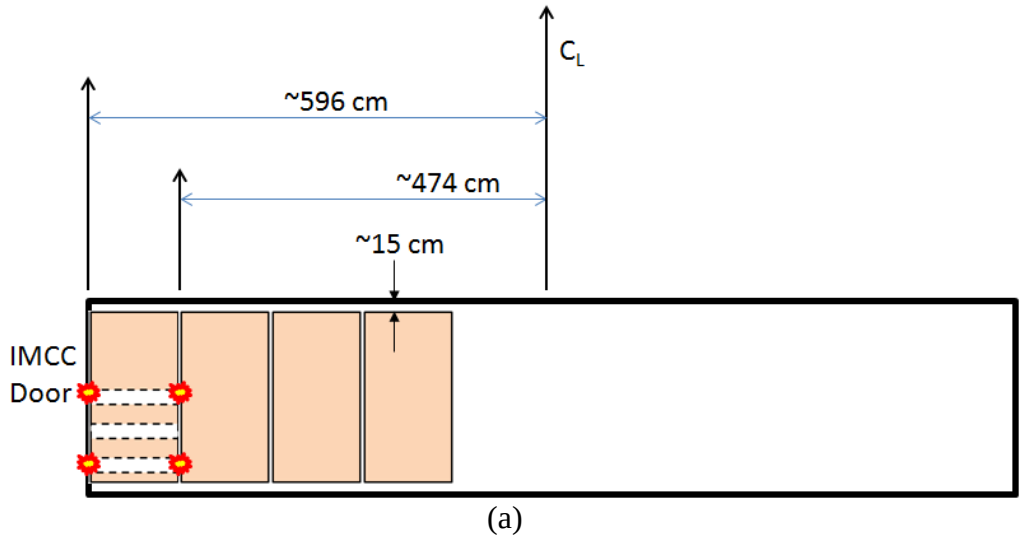
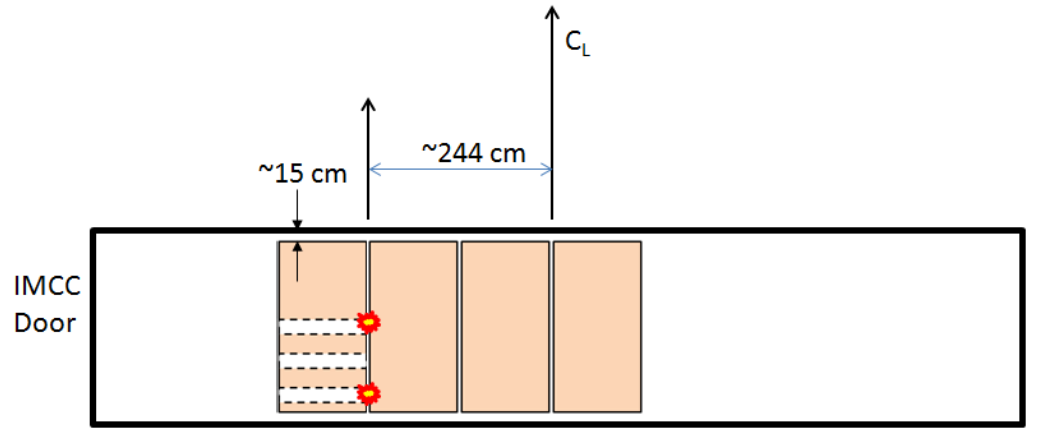
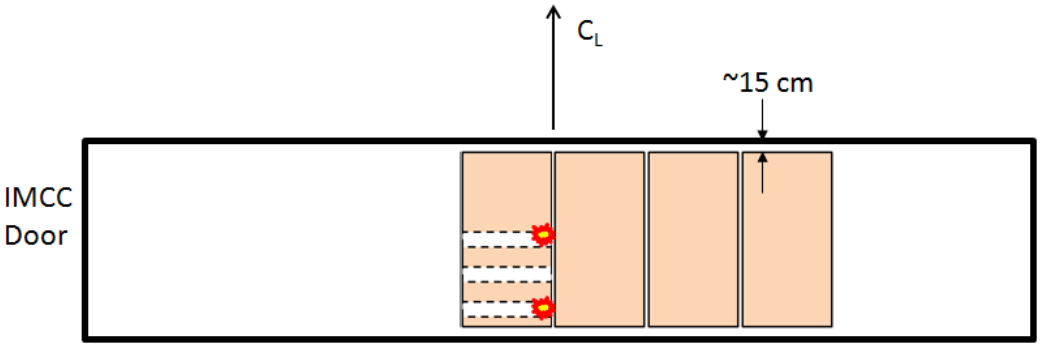


Figure B.2. Shielding configurations and source positions for measurements with the 20-foot container.





(b)



(c)

Figure B.3. Shielding configurations and source positions for measurements with the 40-foot container.

Table B.8: Cargo Shielding Measurement Condition Matrix for 20-Foot Container Using Cs-137

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.2 Reference
			Container Length	Shield Column	Shield Row	
C-20-Cs-1	20	Plywood	-290	1	A	(a)
C-20-Cs-2	20	Plywood	-290	1	B	(a)
C-20-Cs-3	20	Plywood	-290	1	C	(a)
C-20-Cs-4	20	Plywood	-290	1	D	(a)
C-20-Cs-5	20	Plywood	-290	3	A	(a)
C-20-Cs-6	20	Plywood	-290	3	B	(a)
C-20-Cs-7	20	Plywood	-290	3	C	(a)
C-20-Cs-8	20	Plywood	-290	3	D	(a)
C-20-Cs-9	20	Plywood	-168	1	A	(a)
C-20-Cs-10	20	Plywood	-168	1	B	(a)
C-20-Cs-11	20	Plywood	-168	1	C	(a)
C-20-Cs-12	20	Plywood	-168	1	D	(a)
C-20-Cs-13	20	Plywood	-168	3	A	(a)
C-20-Cs-14	20	Plywood	-168	3	B	(a)
C-20-Cs-15	20	Plywood	-168	3	C	(a)
C-20-Cs-16	20	Plywood	-168	3	D	(a)
C-20-Cs-17	20	Plywood	0	1	A	(b)
C-20-Cs-18	20	Plywood	0	1	B	(b)
C-20-Cs-19	20	Plywood	0	1	C	(b)
C-20-Cs-20	20	Plywood	0	1	D	(b)
C-20-Cs-21	20	Plywood	0	3	A	(b)
C-20-Cs-22	20	Plywood	0	3	B	(b)
C-20-Cs-23	20	Plywood	0	3	C	(b)
C-20-Cs-24	20	Plywood	0	3	D	(b)

Table B.9: Cargo Shielding Measurement Condition Matrix for 20-Foot Container Using Ba-133

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.2 Reference
			Container Length	Shield Column	Shield Row	
C-20-Ba-1	20	Plywood	-290	1	A	(a)
C-20-Ba-2	20	Plywood	-290	1	B	(a)
C-20-Ba-3	20	Plywood	-290	1	C	(a)
C-20-Ba-4	20	Plywood	-290	1	D	(a)
C-20-Ba-5	20	Plywood	-290	3	A	(a)
C-20-Ba-6	20	Plywood	-290	3	B	(a)
C-20-Ba-7	20	Plywood	-290	3	C	(a)
C-20-Ba-8	20	Plywood	-290	3	D	(a)
C-20-Ba-9	20	Plywood	-168	1	A	(a)
C-20-Ba-10	20	Plywood	-168	1	B	(a)
C-20-Ba-11	20	Plywood	-168	1	C	(a)
C-20-Ba-12	20	Plywood	-168	1	D	(a)
C-20-Ba-13	20	Plywood	-168	3	A	(a)
C-20-Ba-14	20	Plywood	-168	3	B	(a)
C-20-Ba-15	20	Plywood	-168	3	C	(a)
C-20-Ba-16	20	Plywood	-168	3	D	(a)
C-20-Ba-17	20	Plywood	0	1	A	(b)
C-20-Ba-18	20	Plywood	0	1	B	(b)
C-20-Ba-19	20	Plywood	0	1	C	(b)
C-20-Ba-20	20	Plywood	0	1	D	(b)
C-20-Ba-21	20	Plywood	0	3	A	(b)
C-20-Ba-22	20	Plywood	0	3	B	(b)
C-20-Ba-23	20	Plywood	0	3	C	(b)
C-20-Ba-24	20	Plywood	0	3	D	(b)

Table B.10: Cargo Shielding Measurement Condition Matrix for 20-Foot Container Using Co-60

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.2 Reference
			Container Length	Shield Column	Shield Row	
C-20-Co60-1	20	Plywood	-290	1	A	(a)
C-20-Co60-2	20	Plywood	-290	1	B	(a)
C-20-Co60-3	20	Plywood	-290	1	C	(a)
C-20-Co60-4	20	Plywood	-290	1	D	(a)
C-20-Co60-5	20	Plywood	-290	3	A	(a)
C-20-Co60-6	20	Plywood	-290	3	B	(a)
C-20-Co60-7	20	Plywood	-290	3	C	(a)
C-20-Co60-8	20	Plywood	-290	3	D	(a)
C-20-Co60-9	20	Plywood	-168	1	A	(a)
C-20-Co60-10	20	Plywood	-168	1	B	(a)
C-20-Co60-11	20	Plywood	-168	1	C	(a)
C-20-Co60-12	20	Plywood	-168	1	D	(a)
C-20-Co60-13	20	Plywood	-168	3	A	(a)
C-20-Co60-14	20	Plywood	-168	3	B	(a)
C-20-Co60-15	20	Plywood	-168	3	C	(a)
C-20-Co60-16	20	Plywood	-168	3	D	(a)
C-20-Co60-17	20	Plywood	0	1	A	(b)
C-20-Co60-18	20	Plywood	0	1	B	(b)
C-20-Co60-19	20	Plywood	0	1	C	(b)
C-20-Co60-20	20	Plywood	0	1	D	(b)
C-20-Co60-21	20	Plywood	0	3	A	(b)
C-20-Co60-22	20	Plywood	0	3	B	(b)
C-20-Co60-23	20	Plywood	0	3	C	(b)
C-20-Co60-24	20	Plywood	0	3	D	(b)

Table B.11: Cargo Shielding Measurement Condition Matrix for 20-Foot Container Using Ho-166m

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.2 Reference
			Container Length	Shield Column	Shield Row	
C-20-Ho-1	20	Plywood	0	1	On Top	(b)
C-20-Ho-2	20	Plywood	0	3	On Top	(b)
C-20-Ho-3	20	Plywood	0	1	A	(b)
C-20-Ho-4	20	Plywood	0	1	B	(b)
C-20-Ho-5	20	Plywood	0	1	C	(b)
C-20-Ho-6	20	Plywood	0	1	D	(b)
C-20-Ho-7	20	Plywood	0	3	A	(b)
C-20-Ho-8	20	Plywood	0	3	B	(b)
C-20-Ho-9	20	Plywood	0	3	C	(b)
C-20-Ho-10	20	Plywood	0	3	D	(b)

Note: On Top for Shield Row means the source will be placed on top of the cargo shield.

Table B.12: Cargo Shielding Measurement Condition Matrix for 40-Foot Container Using Cs-137

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.3 Reference
			Container Length	Shield Column	Shield Row	
C-40-Cs-1	40	Plywood	-596	1	A	(a)
C-40-Cs-2	40	Plywood	-596	1	B	(a)
C-40-Cs-3	40	Plywood	-596	1	C	(a)
C-40-Cs-4	40	Plywood	-596	1	D	(a)
C-40-Cs-5	40	Plywood	-596	3	A	(a)
C-40-Cs-6	40	Plywood	-596	3	B	(a)
C-40-Cs-7	40	Plywood	-596	3	C	(a)
C-40-Cs-8	40	Plywood	-596	3	D	(a)
C-40-Cs-9	40	Plywood	-474	1	A	(a)
C-40-Cs-10	40	Plywood	-474	1	B	(a)
C-40-Cs-11	40	Plywood	-474	1	C	(a)
C-40-Cs-12	40	Plywood	-474	1	D	(a)
C-40-Cs-13	40	Plywood	-474	3	A	(a)
C-40-Cs-14	40	Plywood	-474	3	B	(a)
C-40-Cs-15	40	Plywood	-474	3	C	(a)
C-40-Cs-16	40	Plywood	-474	3	D	(a)
C-40-Cs-17	40	Plywood	-244	1	A	(b)
C-40-Cs-18	40	Plywood	-244	1	B	(b)
C-40-Cs-19	40	Plywood	-244	1	C	(b)
C-40-Cs-20	40	Plywood	-244	1	D	(b)
C-40-Cs-21	40	Plywood	-244	3	A	(b)
C-40-Cs-22	40	Plywood	-244	3	B	(b)
C-40-Cs-23	40	Plywood	-244	3	C	(b)
C-40-Cs-24	40	Plywood	-244	3	D	(b)
C-40-Cs-25	40	Plywood	0	1	A	(c)
C-40-Cs-26	40	Plywood	0	1	B	(c)
C-40-Cs-27	40	Plywood	0	1	C	(c)
C-40-Cs-28	40	Plywood	0	1	D	(c)
C-40-Cs-29	40	Plywood	0	3	A	(c)
C-40-Cs-30	40	Plywood	0	3	B	(c)
C-40-Cs-31	40	Plywood	0	3	C	(c)
C-40-Cs-32	40	Plywood	0	3	D	(c)

Table B.13: Cargo Shielding Measurement Condition Matrix for 40-Foot Container Using Ba-133

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.3 Reference
			Container Length	Shield Column	Shield Row	
C-40-Ba-1	40	Plywood	-596	1	A	(a)
C-40-Ba-2	40	Plywood	-596	1	B	(a)
C-40-Ba-3	40	Plywood	-596	1	C	(a)
C-40-Ba-4	40	Plywood	-596	1	D	(a)
C-40-Ba-5	40	Plywood	-596	3	A	(a)
C-40-Ba-6	40	Plywood	-596	3	B	(a)
C-40-Ba-7	40	Plywood	-596	3	C	(a)
C-40-Ba-8	40	Plywood	-596	3	D	(a)
C-40-Ba-9	40	Plywood	-474	1	A	(a)
C-40-Ba-10	40	Plywood	-474	1	B	(a)
C-40-Ba-11	40	Plywood	-474	1	C	(a)
C-40-Ba-12	40	Plywood	-474	1	D	(a)
C-40-Ba-13	40	Plywood	-474	3	A	(a)
C-40-Ba-14	40	Plywood	-474	3	B	(a)
C-40-Ba-15	40	Plywood	-474	3	C	(a)
C-40-Ba-16	40	Plywood	-474	3	D	(a)
C-40-Ba-17	40	Plywood	-244	1	A	(b)
C-40-Ba-18	40	Plywood	-244	1	B	(b)
C-40-Ba-19	40	Plywood	-244	1	C	(b)
C-40-Ba-20	40	Plywood	-244	1	D	(b)
C-40-Ba-21	40	Plywood	-244	3	A	(b)
C-40-Ba-22	40	Plywood	-244	3	B	(b)
C-40-Ba-23	40	Plywood	-244	3	C	(b)
C-40-Ba-24	40	Plywood	-244	3	D	(b)
C-40-Ba-25	40	Plywood	0	1	A	(c)
C-40-Ba-26	40	Plywood	0	1	B	(c)
C-40-Ba-27	40	Plywood	0	1	C	(c)
C-40-Ba-28	40	Plywood	0	1	D	(c)
C-40-Ba-29	40	Plywood	0	3	A	(c)
C-40-Ba-30	40	Plywood	0	3	B	(c)
C-40-Ba-31	40	Plywood	0	3	C	(c)
C-40-Ba-32	40	Plywood	0	3	D	(c)

Table B.14: Cargo Shielding Measurement Condition Matrix for 40-Foot Container Using Co-60

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.3 Reference
			Container Length	Shield Column	Shield Row	
C-40-Co60-1	40	Plywood	-596	1	A	(a)
C-40-Co60-2	40	Plywood	-596	1	B	(a)
C-40-Co60-3	40	Plywood	-596	1	C	(a)
C-40-Co60-4	40	Plywood	-596	1	D	(a)
C-40-Co60-5	40	Plywood	-596	3	A	(a)
C-40-Co60-6	40	Plywood	-596	3	B	(a)
C-40-Co60-7	40	Plywood	-596	3	C	(a)
C-40-Co60-8	40	Plywood	-596	3	D	(a)
C-40-Co60-9	40	Plywood	-474	1	A	(a)
C-40-Co60-10	40	Plywood	-474	1	B	(a)
C-40-Co60-11	40	Plywood	-474	1	C	(a)
C-40-Co60-12	40	Plywood	-474	1	D	(a)
C-40-Co60-13	40	Plywood	-474	3	A	(a)
C-40-Co60-14	40	Plywood	-474	3	B	(a)
C-40-Co60-15	40	Plywood	-474	3	C	(a)
C-40-Co60-16	40	Plywood	-474	3	D	(a)
C-40-Co60-17	40	Plywood	-244	1	A	(b)
C-40-Co60-18	40	Plywood	-244	1	B	(b)
C-40-Co60-19	40	Plywood	-244	1	C	(b)
C-40-Co60-20	40	Plywood	-244	1	D	(b)
C-40-Co60-21	40	Plywood	-244	3	A	(b)
C-40-Co60-22	40	Plywood	-244	3	B	(b)
C-40-Co60-23	40	Plywood	-244	3	C	(b)
C-40-Co60-24	40	Plywood	-244	3	D	(b)
C-40-Co60-25	40	Plywood	0	1	A	(c)
C-40-Co60-26	40	Plywood	0	1	B	(c)
C-40-Co60-27	40	Plywood	0	1	C	(c)
C-40-Co60-28	40	Plywood	0	1	D	(c)
C-40-Co60-29	40	Plywood	0	3	A	(c)
C-40-Co60-30	40	Plywood	0	3	B	(c)
C-40-Co60-31	40	Plywood	0	3	C	(c)
C-40-Co60-32	40	Plywood	0	3	D	(c)

Table B.15: Cargo Shielding Measurement Condition Matrix for 40-Foot Container Using Ho-166m

Measurement	Container length	Shielding Material	Source Position (cm)			Figure B.3 Reference
			Container Length	Shield Column	Shield Row	
C-40-Ho-1	40	Plywood	0	1	On Top	(c)
C-40-Ho-2	40	Plywood	0	3	On Top	(c)
C-40-Ho-3	40	Plywood	0	1	A	(c)
C-40-Ho-4	40	Plywood	0	1	B	(c)
C-40-Ho-5	40	Plywood	0	1	C	(c)
C-40-Ho-6	40	Plywood	0	1	D	(c)
C-40-Ho-7	40	Plywood	0	3	A	(c)
C-40-Ho-8	40	Plywood	0	3	B	(c)
C-40-Ho-9	40	Plywood	0	3	C	(c)
C-40-Ho-10	40	Plywood	0	3	D	(c)

Note: On Top for Shield Row means the source will be placed on top of the cargo shield.

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