SANDIA REPORT

SAND2012-6844
Printed August 2012

EERIS Project

Crane-Mounted Baseline Data Collection Report

Gene Kallenbach

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Crane-Mounted Baseline Data Collection Report

Gene A. Kallenbach
Nuclear Monitoring and Transparency Department
PO Box 5800, MS1374
Sandia National Laboratories
Albuquerque, NM 87185-1374

ABSTRACT

This report describes the Crane-Mounted Baseline Data Collection system and the data collected at an intermodal shipping terminal. The system is designed to characterize the background gamma and neutron radiation environment on a ship-to-shore intermodal container crane. This task is part of the Extreme Environment Radiation Identification System (EERIS) project that is developing a radiation detection system capable of operating in challenging environments.

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1.0 Executive Summary

The Extreme Environment Radiation Identification System (EERIS) project will build a detection system capable of operating in challenging environments. One of the anticipated environments is on the ship-to-shore container crane. As part of EERIS, a data collection exercise was performed to characterize the gamma and neutron background radiation environments on a ship-to-shore container crane. The results indicate that as much as a 9 to 1 change in the gamma count rate may be experienced as the sensor moves from over land to over water. A 2 to 1 change in the neutron count rate was also observed. This highly varying background rate presents a significant challenge to detection systems fielded in this environment.

2.0 Introduction

2.1 Program Overview

The Extreme Environment Radiation Identification System (EERIS) is a technology development project sponsored by the National Nuclear Security Agency's (NNSA) NA-22 organization. The objective of this project is to develop environmentally hardened spectroscopic radiation detection technologies suitable for use in unattended outdoor environments. Possible locations for use of the developed technologies include intermodal container handling equipment, off-road vehicles, marine (boat or pier mounted) handheld or backpack applications.

The technologies developed include scintillation crystals, photomultiplier tubes, multi-channel analyzers, and associated software. Emphasis is placed on technologies useful for multi-sensor, compact, low-power, self-calibrating, long-life systems while achieving laboratory-grade radiation detection and identification performance. In addition to the environmental challenges, applications that result in a highly varying background such as mobile detection applications will be addressed.

A prototype multi-sensor system comprised of gamma and neutron sensor elements will be designed, built and tested for this project. Testing will consist of simulated environments using the environmental test facilities at Sandia National Laboratories. To provide relevance to real-world environments, a Baseline Data Collection task was undertaken in which field environments are characterized.

2.2 Purpose

The purpose of the Crane-Mounted Baseline Data Collection task is to characterize the environment on a ship-to-shore intermodal container crane. Figure 1 shows a typical crane. The specific location selected is on the spreader-bar, which is the device that attaches to the intermodal container. The sensors are mounted on the bottom of the crane spreader-bar. The collection system's Control Unit, which is the data-logging component, is located on the crane head-block. The head-block is the device that attaches to the spreader-bar (Figure 2). The collection system's User Interface is housed in a transit case and is located near the base of the crane. Data elements to be collected include:

- Gamma radiation background including variations as the crane moves
- Neutron radiation background including variations as the crane moves
- Temperature data
- Shock data and vibration data

Figure 1. Ship-to-Shore Container Crane

Figure 2. Spreader-bar and Head-block

3.0 Baseline Data Collection System Description

The Baseline Data Collection System is designed to collect background radiation and environmental data associated with the ship-to-shore container crane environment. The Baseline Data Collection System is a self-contained, battery-powered, gamma and neutron sensor system (Figure 3).

Figure 3. Baseline Data Collection System

The Control Unit contains processing, data recording, communication and power components. It samples the data at user-defined intervals and stores the data for later retrieval. It has sufficient battery capacity to run the system for approximately 8 hours. A radiofrequency (RF) communication link allows the data collection system operator to remotely monitor the status of the system while the crane is in operation.

3.1 Gamma Sensor

Type: Sodium iodide (NaI), stainless steel clad
Quantity: 1 each
Size: 2-inch dia. by 18-inch length
Energy range: Approximately 30 keV to 3 MeV

The gamma sensor consists of a 2-inch-dia. by 18-inch-long sodium iodide (NaI) crystal and photo-multiplier tube (PMT) coupled to a commercial ICx dsiSPEC multi-channel analyzer (MCA). A ¼ -inch-thick Ecomass (11-gm/cc tungsten-loaded epoxy) shield is placed on the back half of the sensor to reduce the amount of background radiation received from above the detector.

The sensor, PMT and MCA are shock mounted in five Sorbethane shock isolators (Figure 4). The sensor is contained in a 1/8-inch-thick aluminum enclosure except for the front face. The front face (lid) is fabricated from ¼-inch aluminum with two 4.25-inch by 7.25-inch areas milled down to 0.063 inch thick (Figure 5). An accelerometer is mounted to the enclosure to record shock and vibration data.

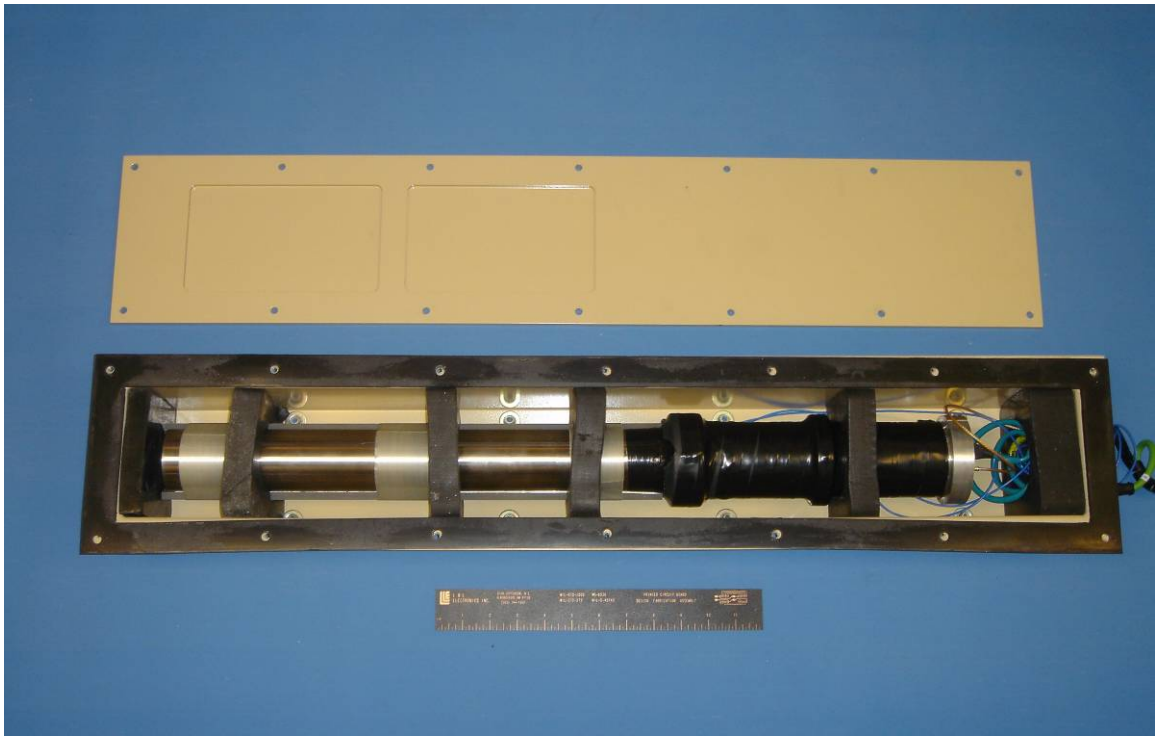


Figure 4. Gamma Sensor

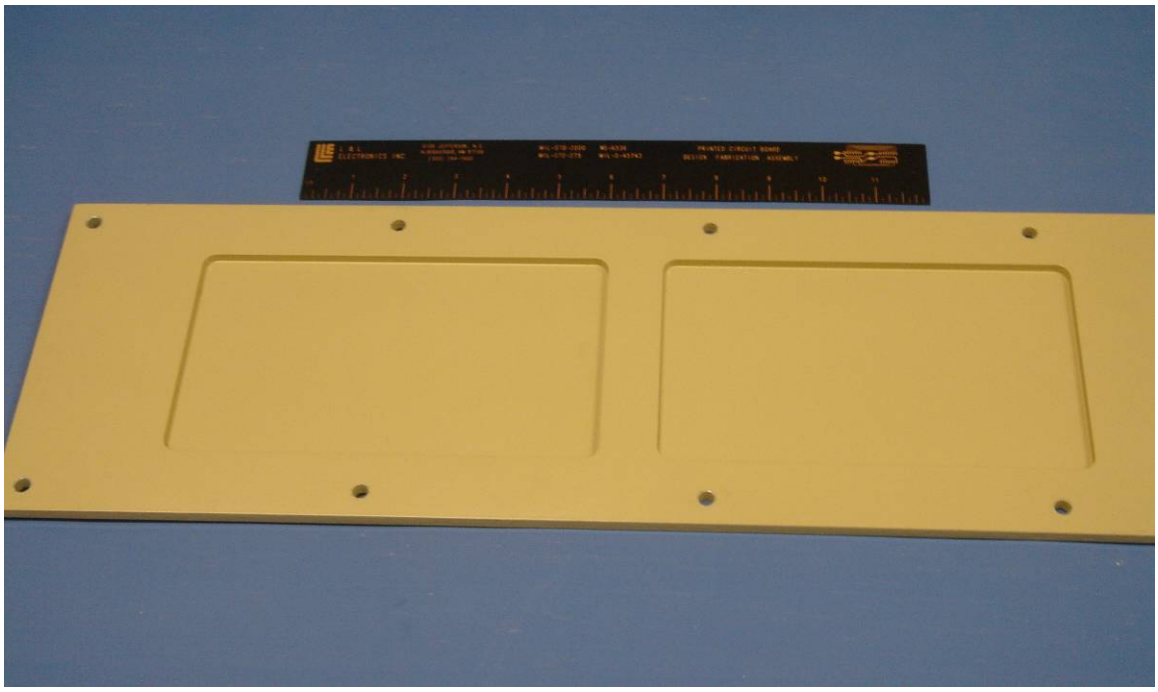


Figure 5. Gamma Sensor Front Cover

3.2 Neutron Sensor

Type: Helium-3 tubes
Quantity: two each
Size: 2-inch dia. by 20-inch length, active area
Pressure: 2 atmospheres

The Neutron sensor consists of two 2-inch-dia. by 20-inch-long Helium-3 tubes coupled to a commercial Precision Data Technologies neutron electronics module. The front of the tubes is covered by ½-thick high-density polyethylene. The back side of the tubes is covered in 2-inch-thick high-density polyethylene.

The sensors and polyethylene are mounted in four Sorbethane shock isolators inside a 1/8-inch-thick aluminum enclosure (Figure 6). An accelerometer is mounted to the enclosure to record shock and vibration data.

Figure 6. Neutron Sensor

3.3 Control Unit

The Control Unit contains processing, data recording, communication and power components (Figure 7). For this collection effort, it was set up to record gamma spectra and neutron counts over sequential 1-second intervals. An industrial computer with a Linux operating system and custom software performs the data collection and processing functions. It stores the data for later retrieval in a database structure. This allows up to 8 hours of data to be recorded between downloads.

The Control Unit has internal batteries. It has sufficient battery capacity to run the system for approximately 8 hours. An RF communication link allows the data collection system operator to remotely monitor the status of the system while the crane is in operation. Figure 10 points out the individual Control Unit components.

Figure 7. Control Unit

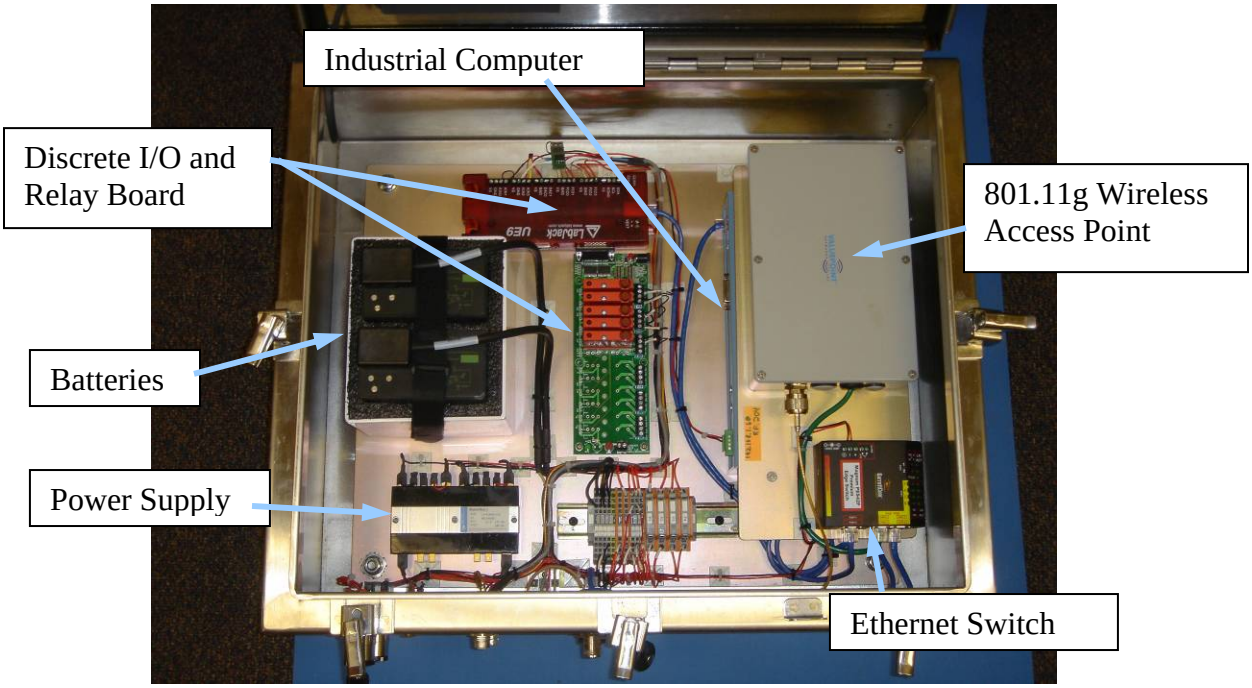


Figure 8. Control Unit Interior

3.4 Operator Interface

The Operator Interface (Figure 9) allows the user to remotely monitor the status and download data from the data collection system. It contains a wireless client for communicating with the Control Unit, a sealed keyboard, a daylight viewable LCD screen, and an industrial computer. These components are housed in a watertight transit case. Batteries for the Operator Interface are housed in separate watertight transit cases (Figure 10). The batteries can run the Operator Interface for up to 8 hours.

Figure 9. Operator Interface

Figure 10. Operator Interface Batteries

4.0 Data Collection Plan

4.1 Dates and Site

Data was collected on September 23rd and 24th, 2008, at the Husky Terminal at the Port of Tacoma, Tacoma, Washington (Figure 11).

Figure 11. Husky Terminal at the Port of Tacoma

4.2 Data Collection Scenarios

For this data collection event, no ship was present during the measurements. The desire was to collect the background data without the unknown variables of a ship and cargo present. If possible, a second data collection during loading and unloading (discharge) of real cargo will be performed at a later date.

Three data collection scenarios were executed:

1) Long dwell (10-minute) static collections at 10 locations along a typical crane trajectory, no container present

2) Long dwell (10-minute) static collections at 10 locations along a typical crane trajectory, with an empty container present
3) Contiguous 1-second (dynamic) collections while the crane is moving along a typical trajectory, no container present.

4.2.1 Static Data Collections

For the static collections, 10 locations were preselected. Table 1 lists the positions at which measurements were taken; corresponding locations are shown in Figure 12. The crane contains a display that indicates the hoist (vertical) and trolley (horizontal) location, in feet, of the spreader-bar.

Table 1. Static Measurement Locations

Position No.	Hoist Location (feet)	Trolley Location (feet)
1	94	94
2	70	94
3	40	110
4	10	140
5	10	170
6	10	200
7	20	230
8	40	250
9	70	250
10	94	250

Two sets of static data were taken, one with an empty spreader-bar and a second set with an empty container attached to the spreader-bar. Both sets used the same measurement locations. It was desired to use a loaded container in the second set, but union rules require that a union crane operator and support staff be employed when moving loaded shipping containers. As the Port was using maintenance personnel to operate the crane to reduce the cost, using a loaded container was prohibited. The empty container was not sea-worthy, so it was designated as a test item by the Port and therefore was exempt from union rules.

Figure 12. Static Measurement Locations

4.2.2 Dynamic Measurements

To collect dynamic data, the collection system was set to continuously collect and store 1-second spectra. A video camera was set up to record the time and location of the spreader-bar during the test. The clock on the video camera was synchronized to the clock on the data collection system. The crane operator was instructed to simulate load and unload cycles by moving the spreader-bar between Position 1 and Position 10 using a typical trajectory. At the end points of each path, the crane operator was instructed to wait approximately 10 seconds to provide some amount of time separation between recordings. Ten complete cycles from Position 1 to Position 10 and back to Position 1 were recorded with an unloaded spreader-bar.

5.0 Data Collection Preparation

5.1 Planning Meeting and Mounting Brackets

This data collection was conducted as part of crane maintenance activities – i.e. maintenance personnel were operating the crane and no actual cargo was involved in the collection. As such, no coordination with union or law enforcement personnel was required.

A data collection planning meeting was held at the Port of Tacoma on June 11th, 2008. The details of how to conduct the test and how to attach the equipment were discussed at this meeting. Following this meeting, designs for the mounting brackets were developed. The designs were sent to the Port for approval by the Crane Engineer. Following approval, the brackets were fabricated and instruction and installation drawings prepared. The kit containing parts and instructions was sent to the Port, where their crane service personnel welded the brackets to the spreader-bar.

The gamma and neutron sensors were located on opposite corners of the bottom of the spreader-bar. The Control Unit was located on a work platform near the top of the head-block. Figure 13 through Figure 17 show the installation.

5.2 Installation and Checkout

The Data Collection System and spare parts were crated and shipped to the Port the week of September 15th. At 8:00 AM on the morning of September 23rd, test personnel from Sandia National Laboratories, Kansas City Plant/Kirtland Operations (Honeywell/FM&T) and the Port of Tacoma arrived on site and began equipment installation and checkout. By 10:00 AM installation and checkout were complete. During this time, a calibration spectrum was recorded. To ensure a well-defined peak, four 11-ounce containers of dietary salt substitute (potassium chloride) were attached to the face of the gamma sensor (Figure 18) and a 10-minute calibration spectrum was collected (Figure 19).

Figure 13. Neutron Sensor Installation

Figure 14. Gamma Sensor Installation

Figure 15. Control Unit Installation

Figure 16. Control Unit Installed

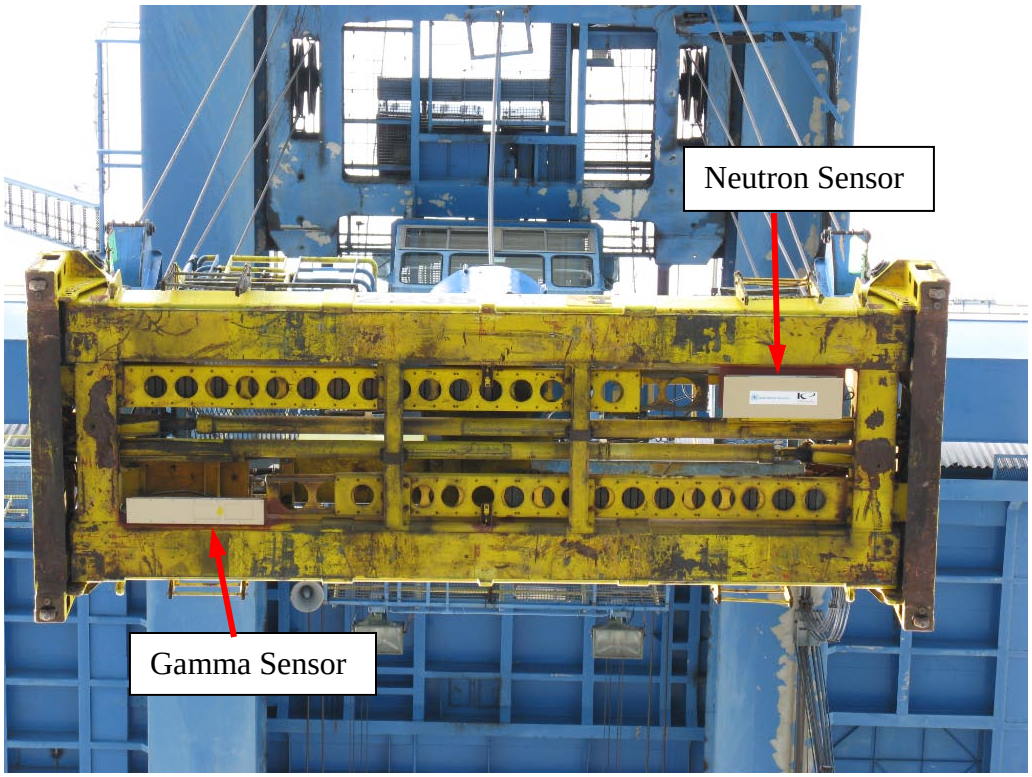


Figure 17. Gamma and Neutron Sensors Installed

Figure 18. Calibration

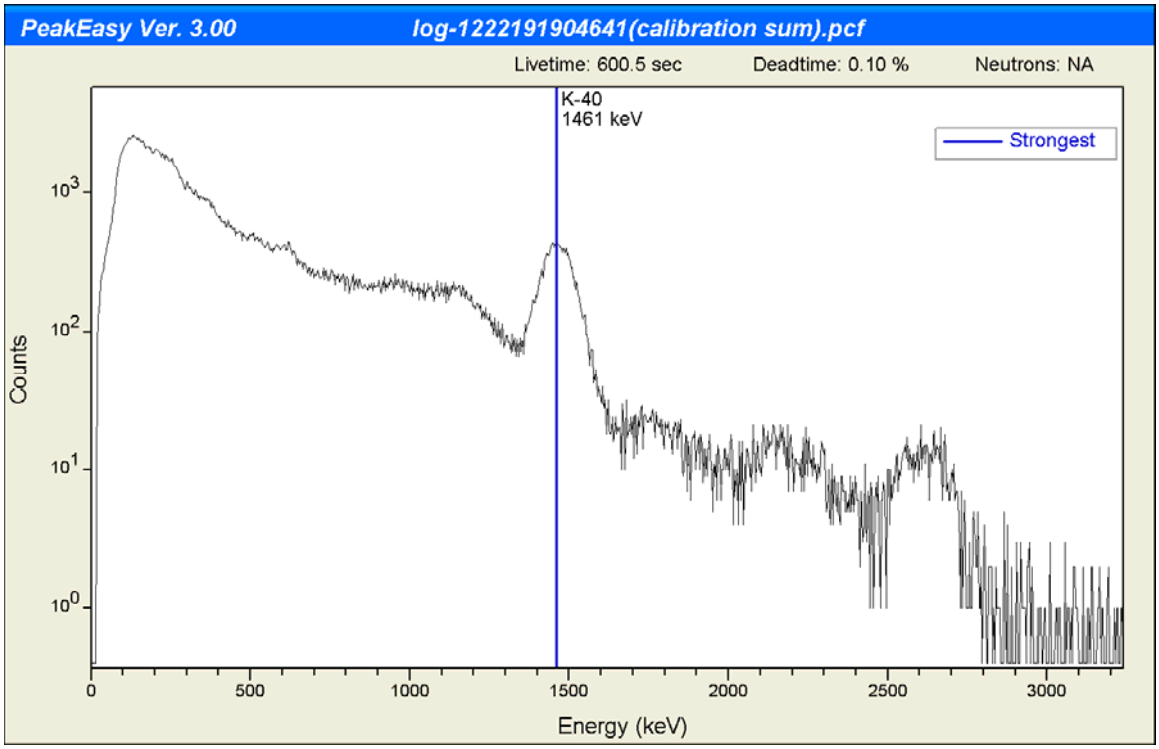


Figure 19. Calibration Spectrum

6.0 Data Collection

6.1 Static Test Results

6.1.1 Unloaded

Resulting spectra for Positions 1 through 10 (unloaded) are shown in Appendix A. A comparison of Positions 1 and 10 is shown in Figure 20.

6.1.2 Empty Container

Resulting spectra for Positions 1 through 10 (empty container) are shown in Appendix B. Figure 21 shows the results for Positions 1 and 10.

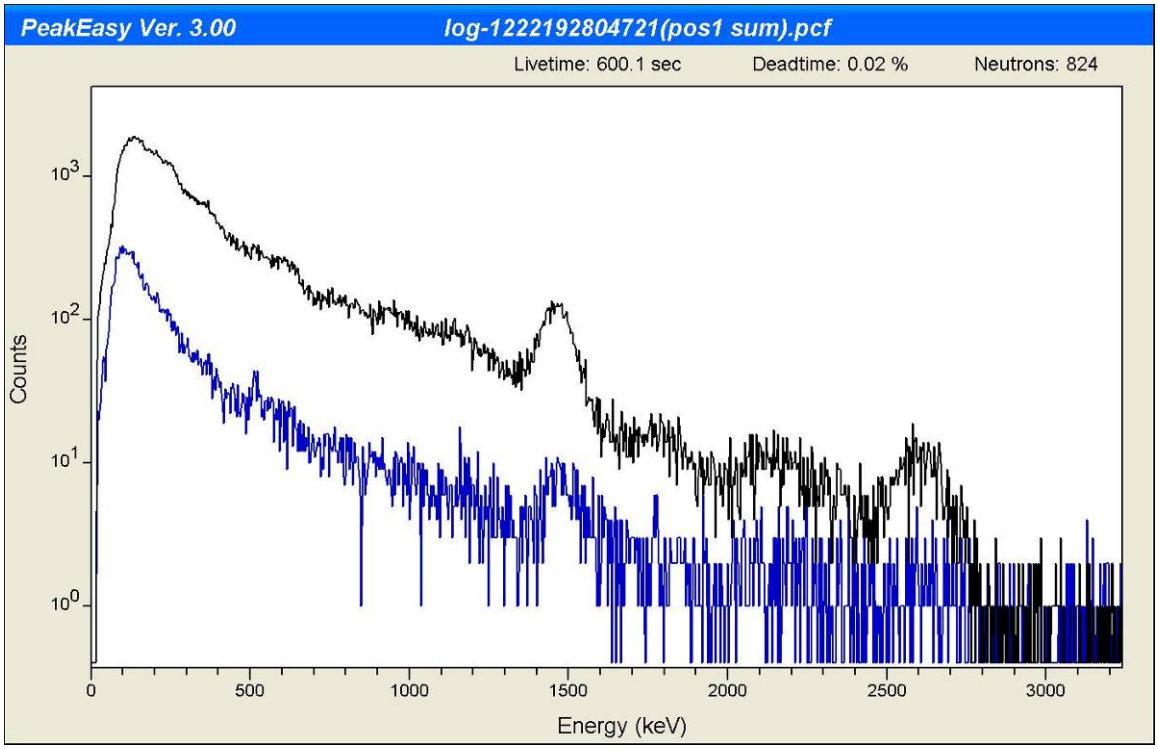


Figure 20. Position 1 (Black) and Position 10 (Blue), Unloaded

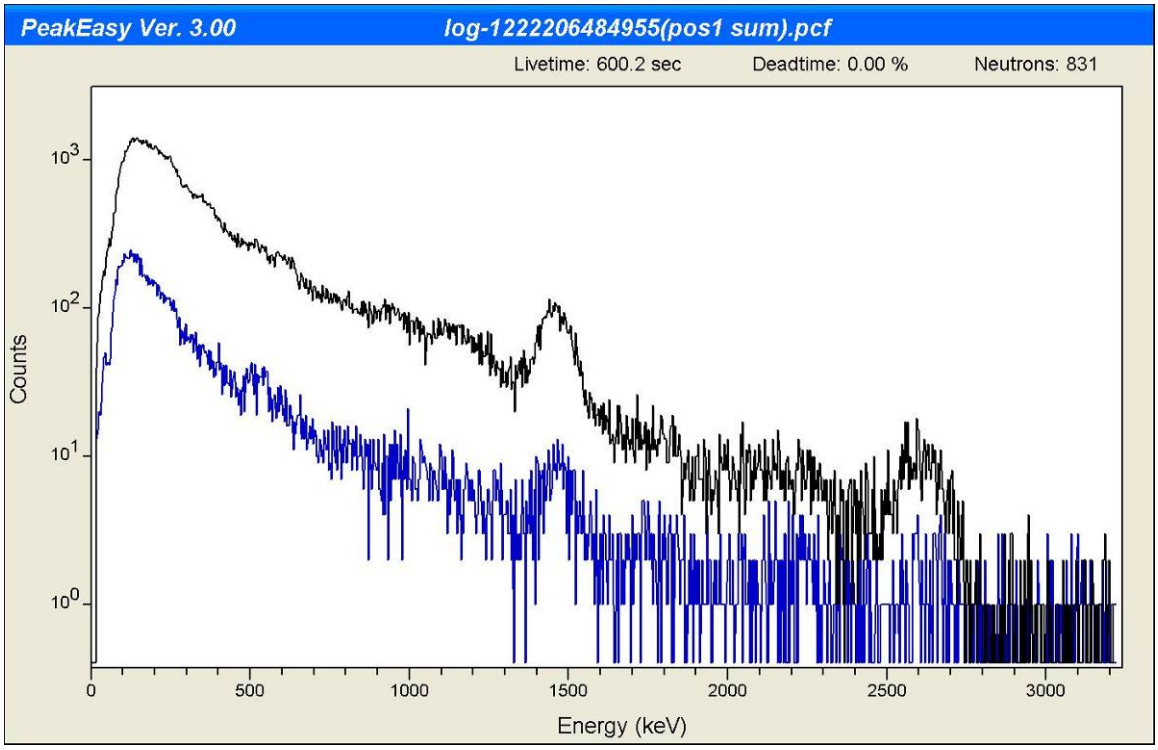


Figure 21. Position 1 (Black) and Position 10 (Blue), Empty Container

6.1.3 Static Data Comparison

Appendix C contains a tabulation of the static data collected. Figure 22 shows the gamma count rates plotted versus position. Figure 23 shows the neutron count rates plotted versus position:

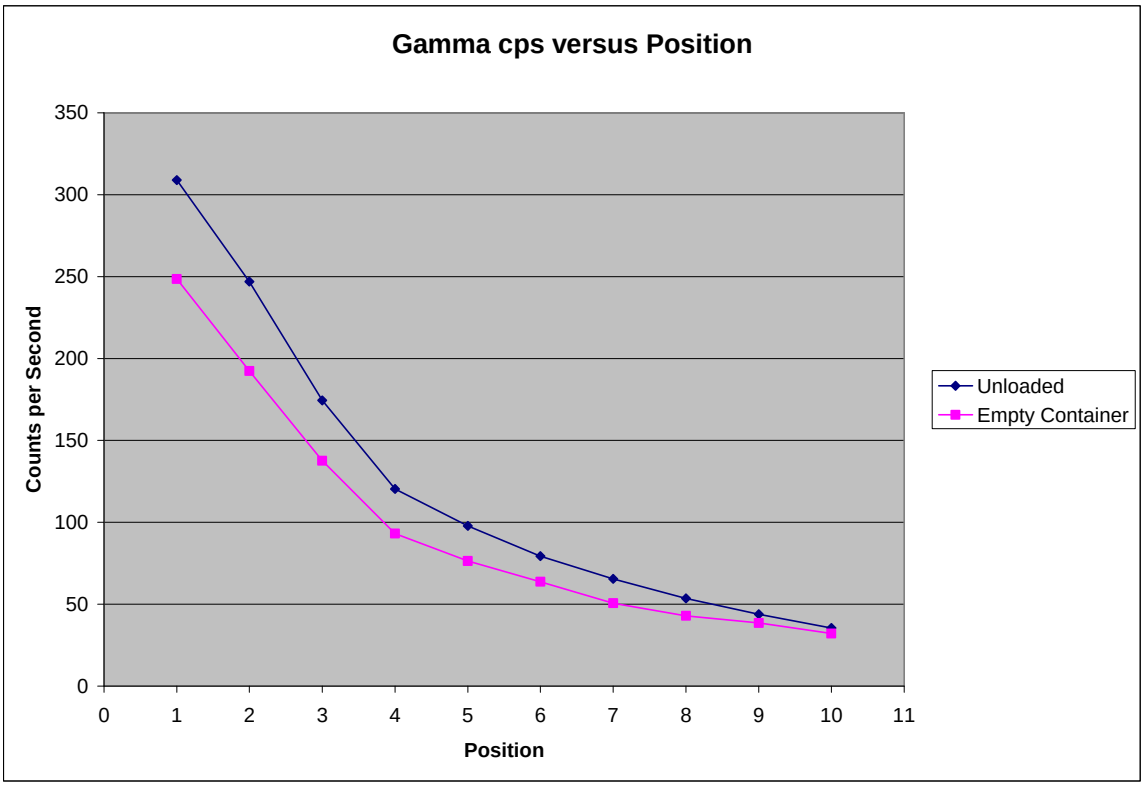


Figure 22. Gamma Count Rate versus Position

The difference between an unloaded spreader-bar and one with an empty container can be explained by the shielding effect of the container. When over the quay, the naturally occurring radioactive material (NORM) is shielded by the container. When over the water, the NORM signature has fallen off significantly so there is little difference between the Unloaded and Empty Container conditions. The reduction in background rate is still significant in both cases. In the Unloaded case, the count rate for Position 10 is only 11.5% of Position 1. In the Empty Container case, the count rate for Position 10 is 12.9% of Position 1.

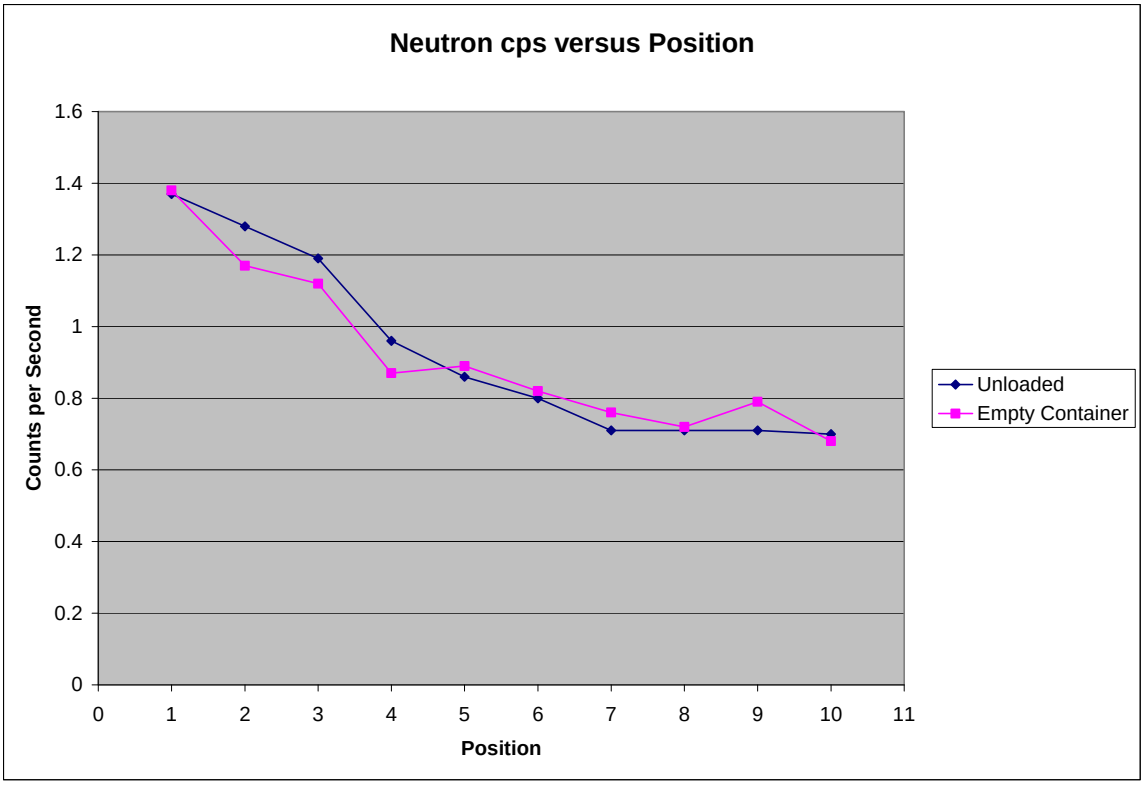


Figure 23. Neutron Count Rate versus Position

The gamma count rate is more affected by position than the neutron count rate. A possible explanation for this is that the neutron background is primarily due to cosmic sources. With a sufficiently moderated He-3 detector, positioning over the land or water should not show much difference. In spite of this, a significant reduction in the count rate is still evidenced. For the Unloaded case, Position 10 is 51% of Position 1. For the Empty Container case, Position 10 is 49% of Position 10. A possible explanation for this is that as the detector is moved further from the quay, it is also being moved further from the steel structure of the crane. The interaction between high-energy cosmic radiation and steel will produce neutrons so as the detector is moved further away, a reduction in count rate should occur.

6.2 Dynamic Test Results

Ten cycles of the crane were performed with the spreader-bar empty. The crane operator was instructed to simulate the loading or unloading trajectory while the crane was moving between locations: Hoist = 94 feet, Trolley = 94 feet and Hoist = 94 feet, Trolley = 250 feet.

6.2.1 Gamma Dynamic Test Results

Predictably there is scatter in the data due to the variance in the time it took the operator to complete a cycle. The average time to complete an outbound portion was 54.2 seconds (Figure 24) and the average time to complete the return portion was 47.6 seconds (Figure 25).

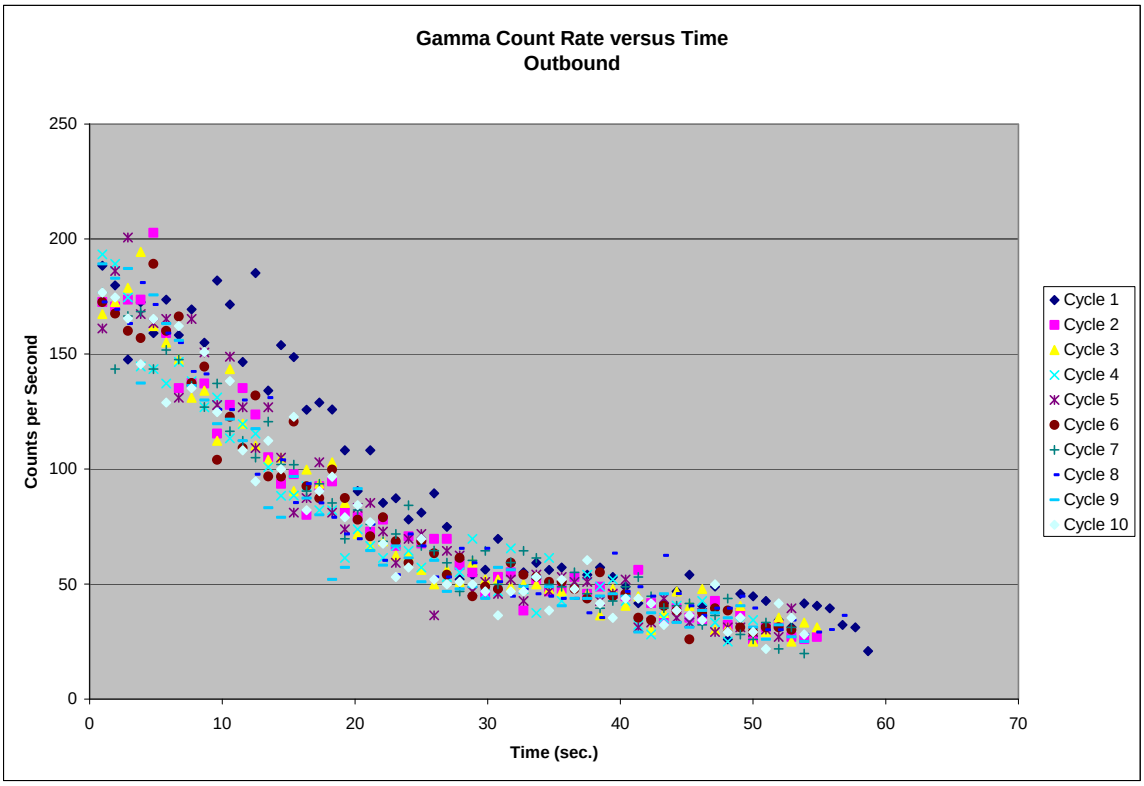


Figure 24. Gamma Count Rate versus Time during outbound portion of cycle

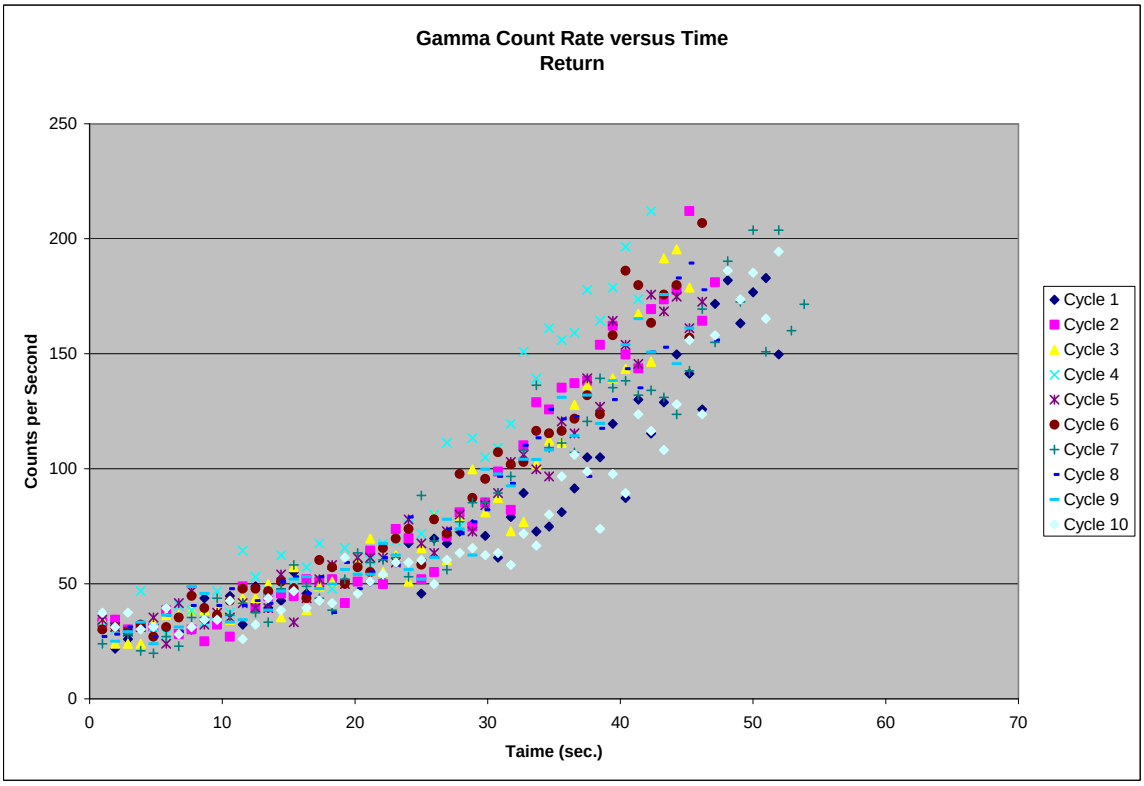


Figure 25. Gamma Count Rate versus Time during return portion of cycle

6.2.2 Neutron Dynamic Test Results

Figure 26 shows the neutron count rate versus time for the outbound portion of the cycle. Figure 27 shows the neutron count rate versus time for the return portion of the cycle. Due to the low count rate, the results are predictable. The neutron counts typically remain in the 0 to 4 neutrons per second range regardless of where the spreader bar is located.

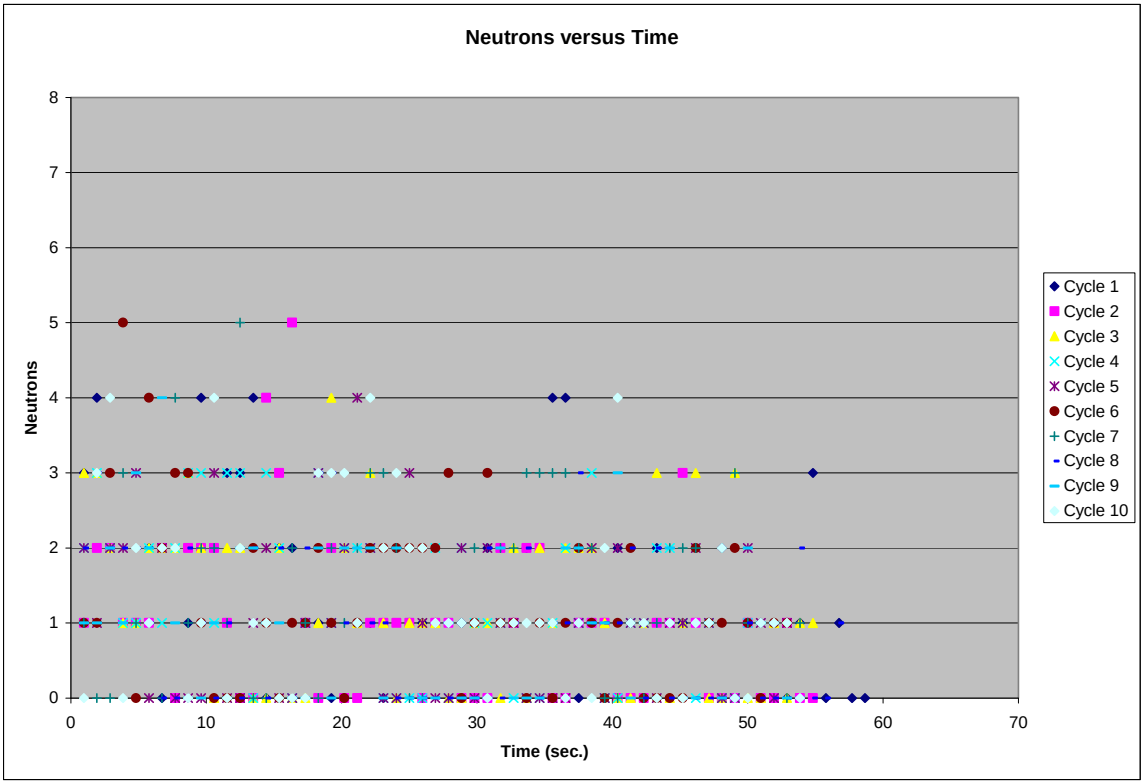


Figure 26. Number of neutrons recorded versus time during outbound portion of cycle

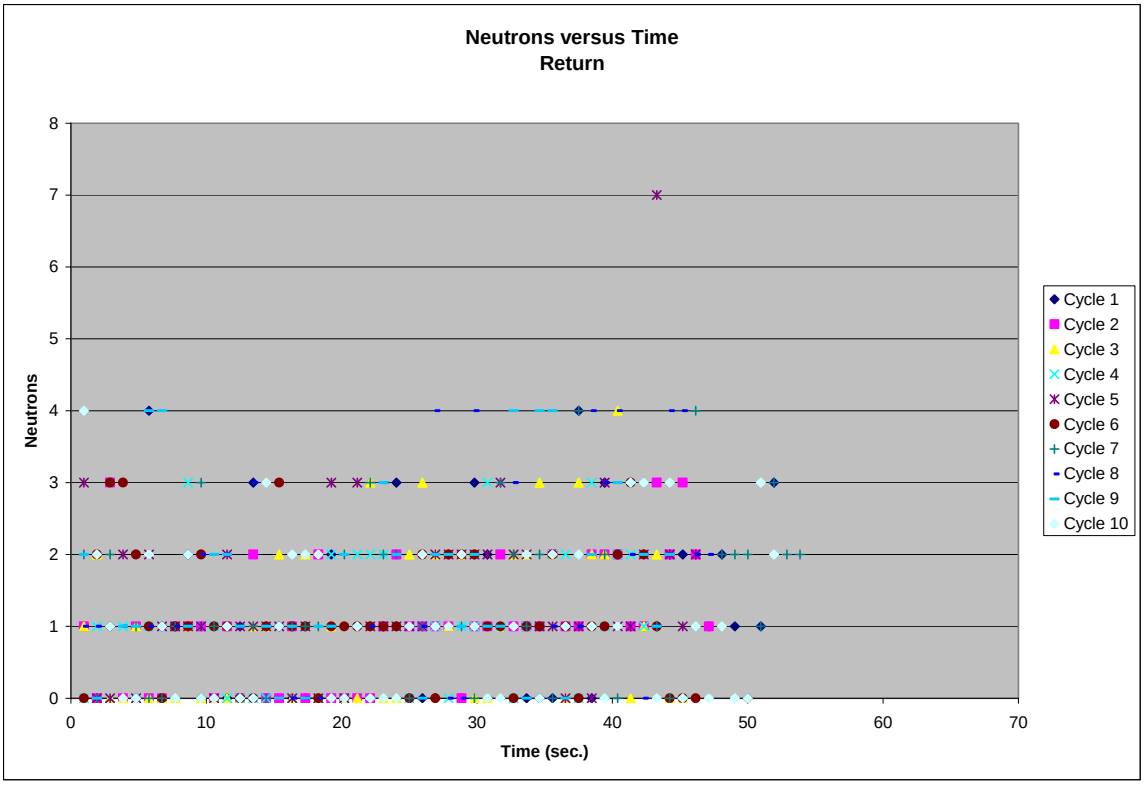


Figure 27. Number of neutrons recorded versus time during return portion of cycle

7.0 Conclusion

The results of this data collection exercise indicate that as much as a 9 to 1 change in the gamma count rate may be experienced as the sensor moves from over land to over water. A 2 to 1 change in the neutron count rate was also observed when long integration times were used. This highly varying background rate presents a significant challenge to detection systems fielded in this environment. In addition, the data presented here does not include the effects of a ship and cargo. A second round of testing on live cargo is highly desirable to complete the data set.

A detection system using a typical fixed sigma above background alarm threshold and a sliding time integration window may not yield very good sensitivity. An alternative approach is to use the landed/free or latched/unlatched signals from the spreader-bar as an occupancy sensor. Integration time can then be tied to the time a container is being moved to generate the foreground spectrum. Likewise, the background spectrum can be recorded during the empty return swing of the crane. This still may not yield adequate performance. Adding the position and time information from the crane may improve the performance. This will allow a time/position dependant series of background spectra to be subtracted from a time/position dependant series of foreground spectra. The resulting net spectrum should be a more accurate measure of the spectrum of the cargo. Coupling this to a fast isotope identification algorithm may allow determination of the radioisotope present before the container is released from the spreader-bar. If a potential problem is

suspected, it is plausible that the detection system could inhibit release of the container to allow additional integration time, which will generate better statistical data for positive radioisotope identification. As long as this does not occur more than once per 1000 containers, it will not significantly affect the flow of commerce.

Appendix A: Static Tests, Unloaded

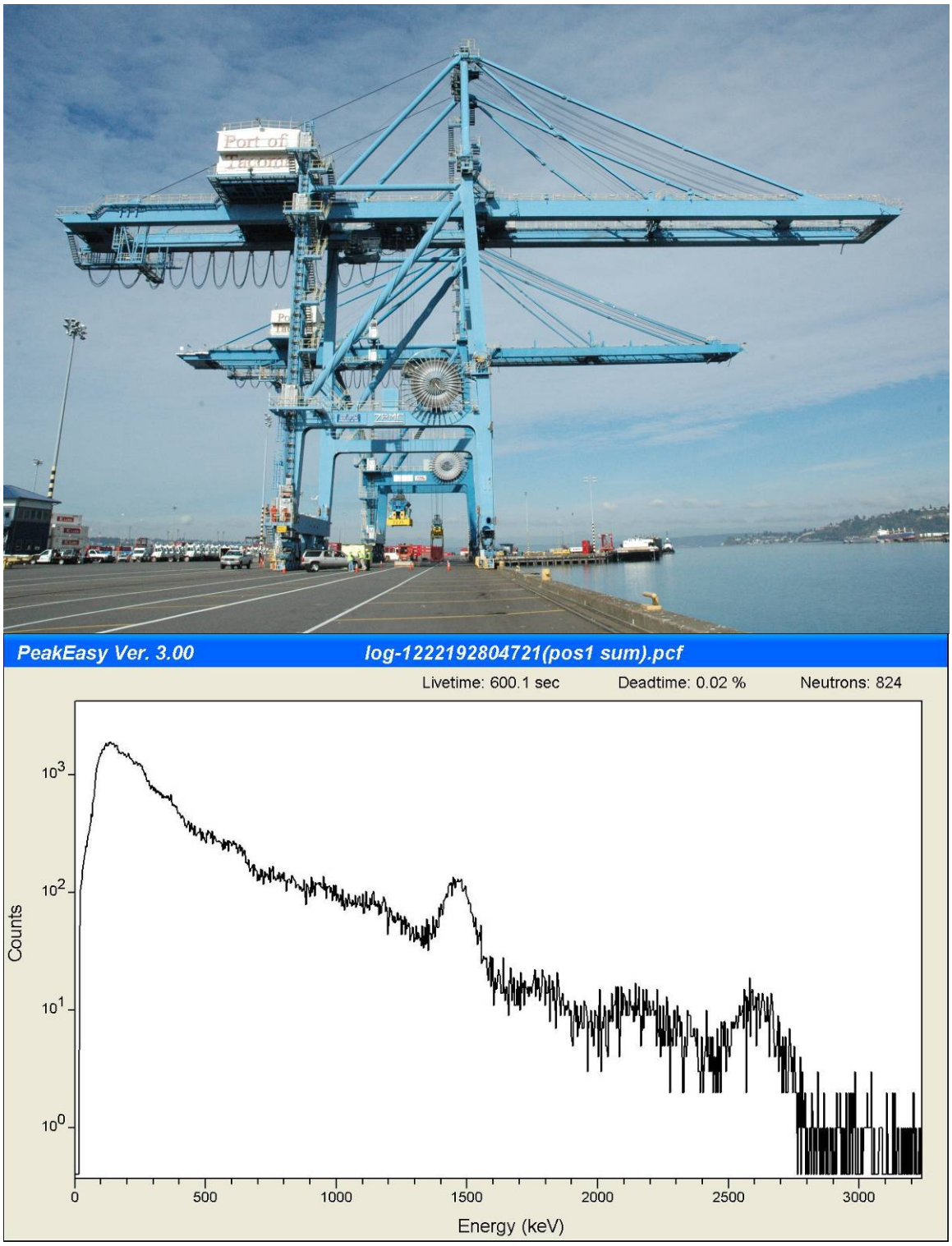


Figure A-1. Position 1, Unloaded

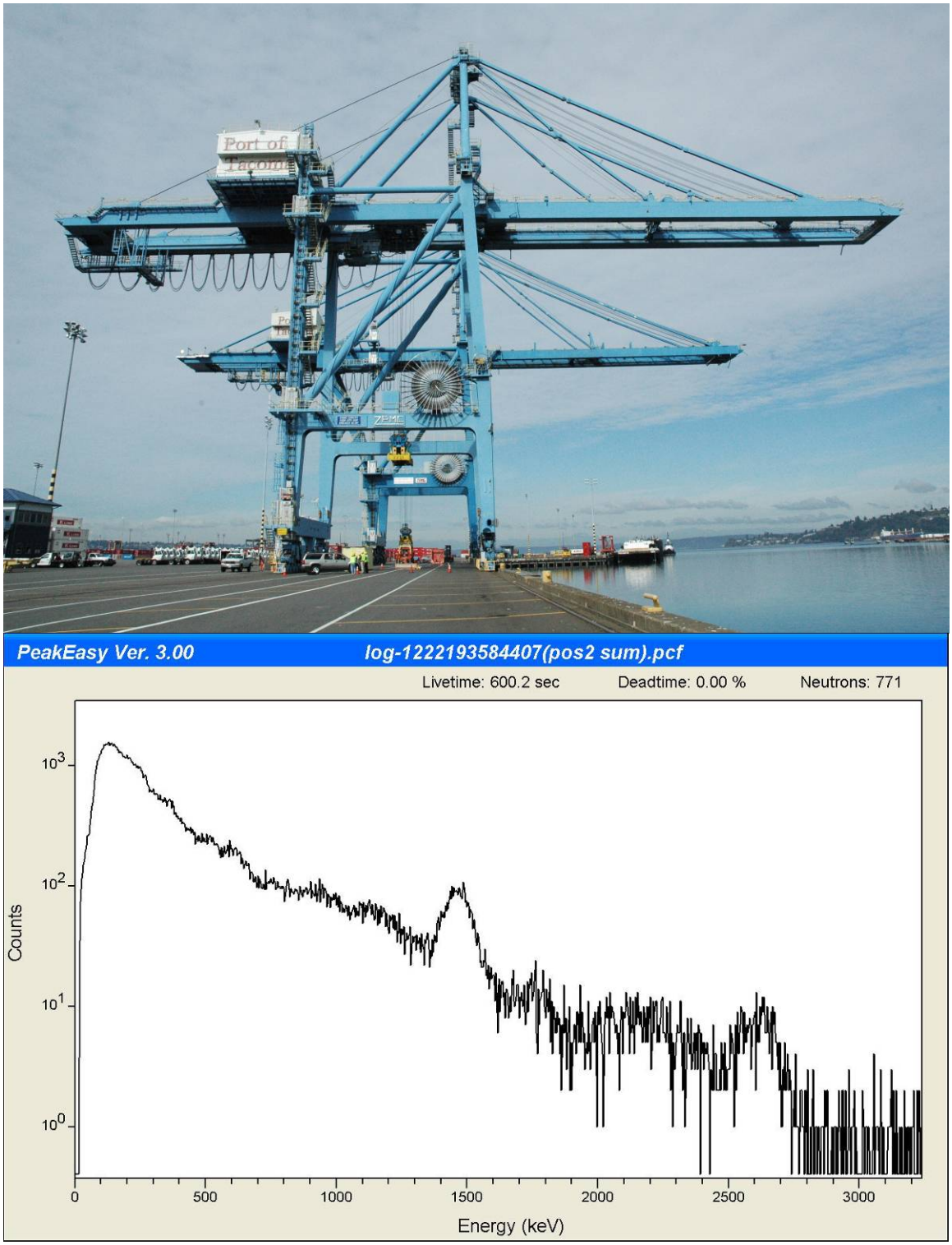
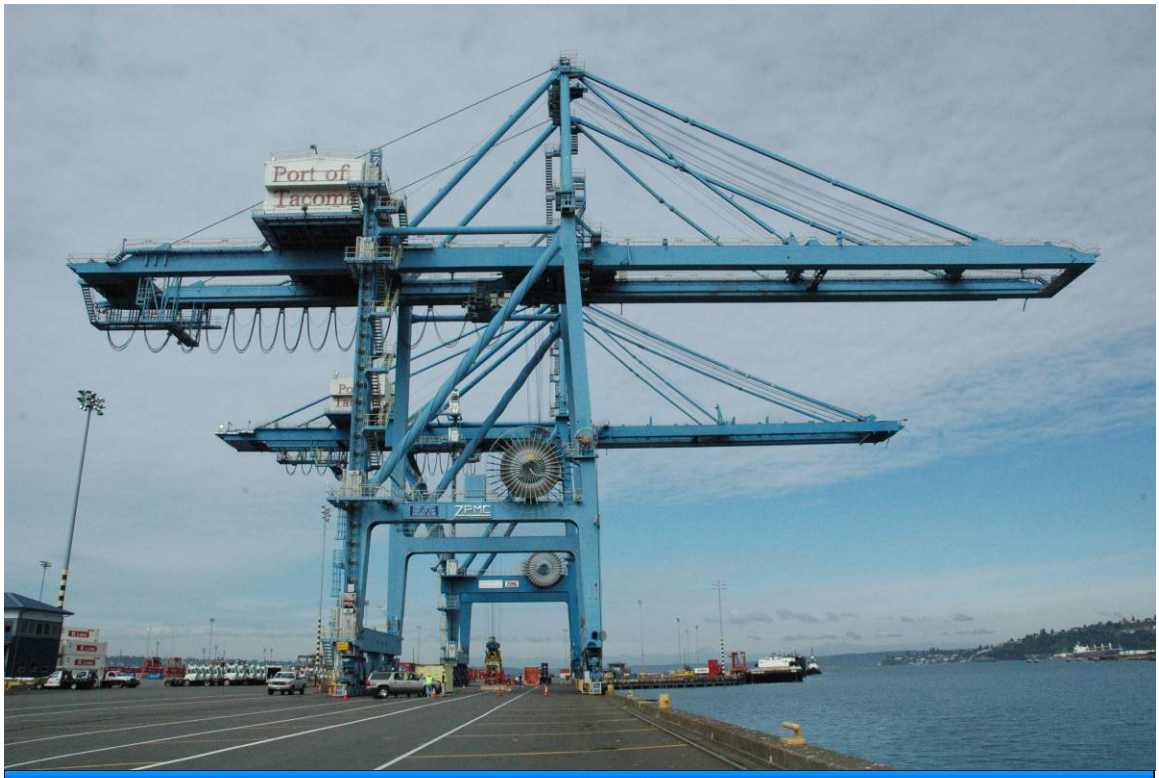


Figure A-2. Position 2, Unloaded



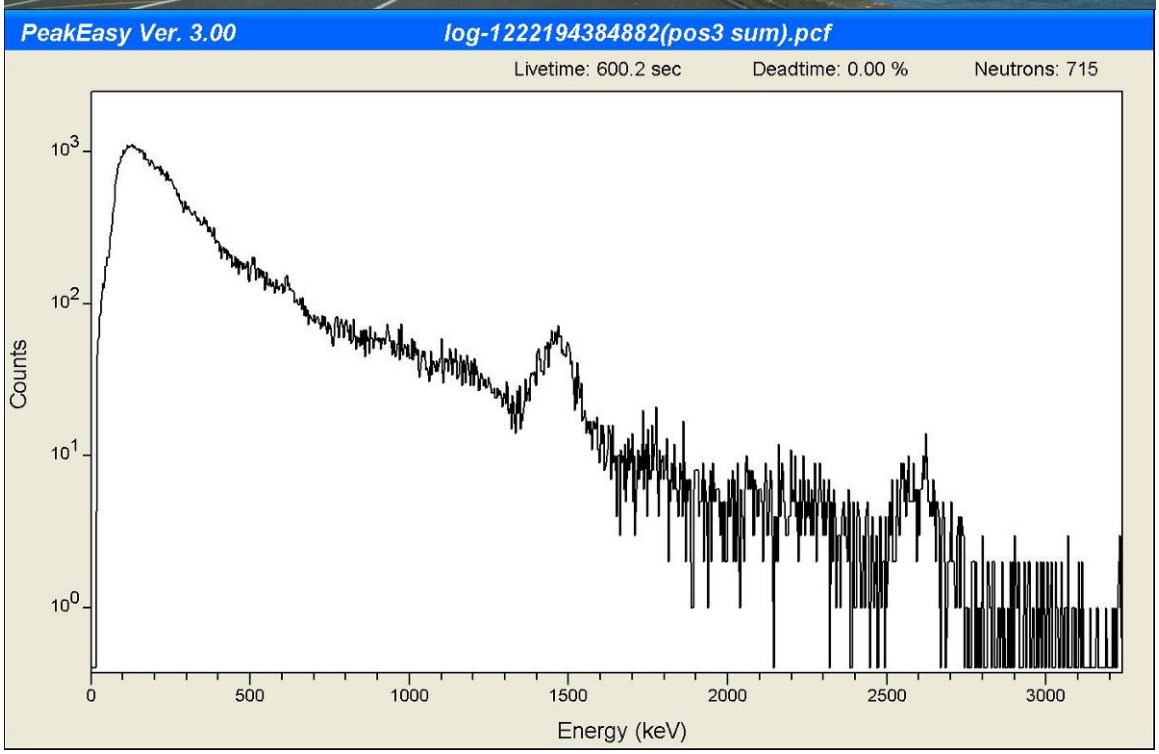
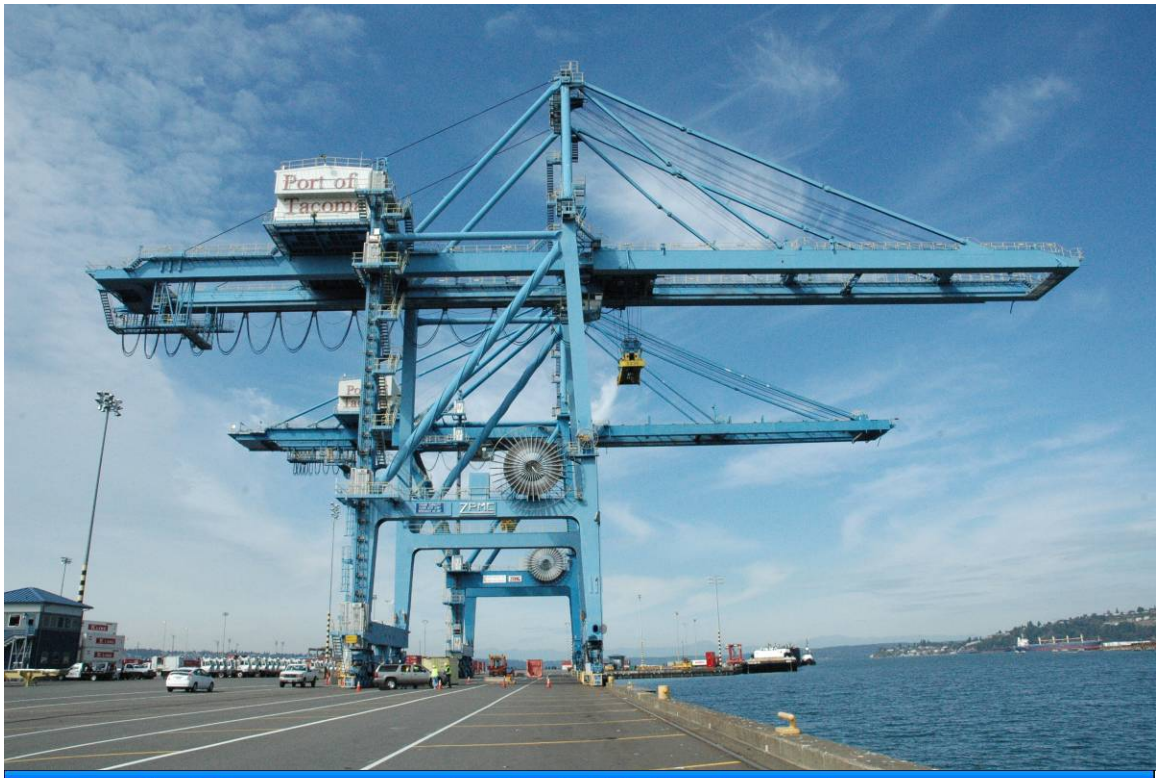


Figure A-3. Position 3, Unloaded



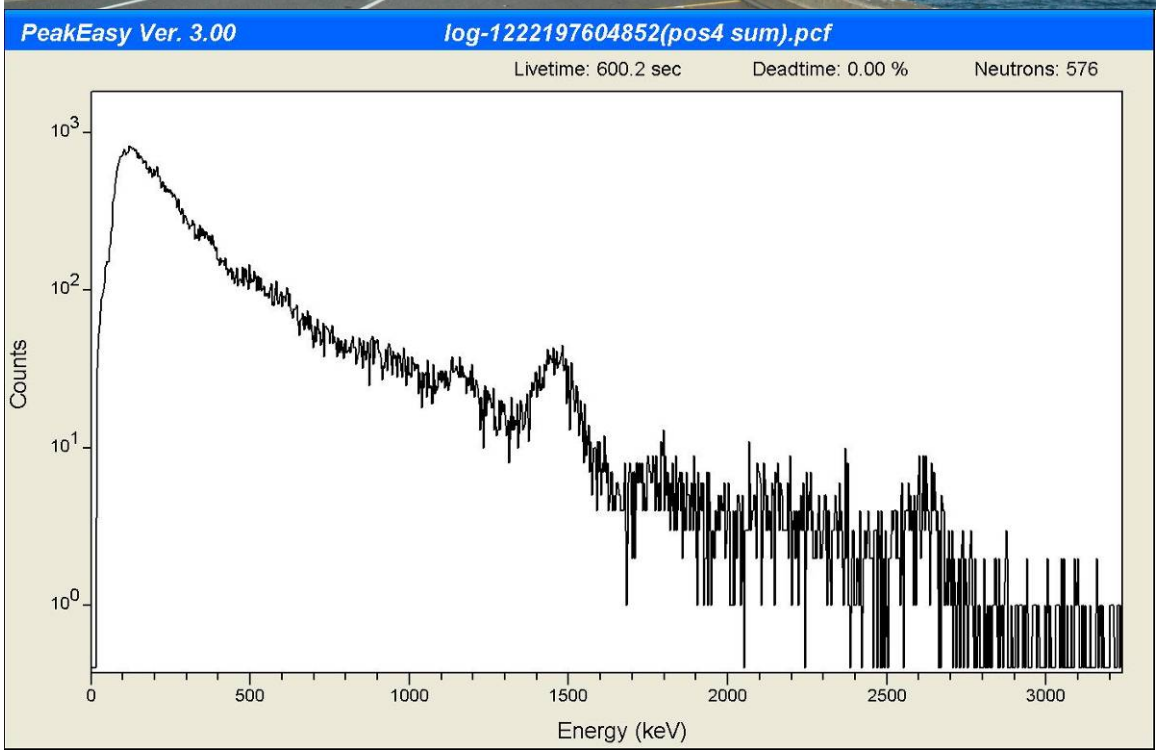


Figure A-4. Position 4, Unloaded

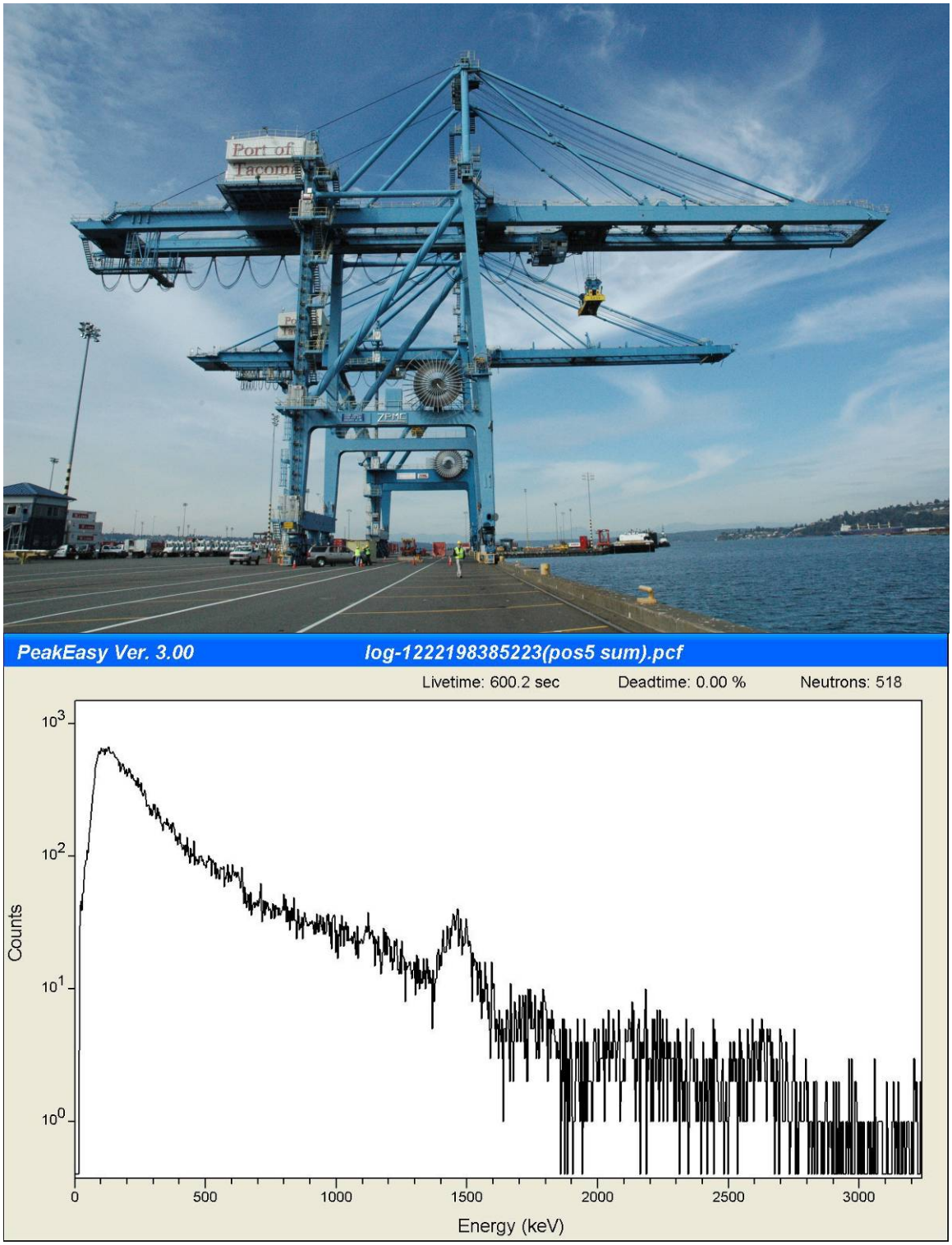
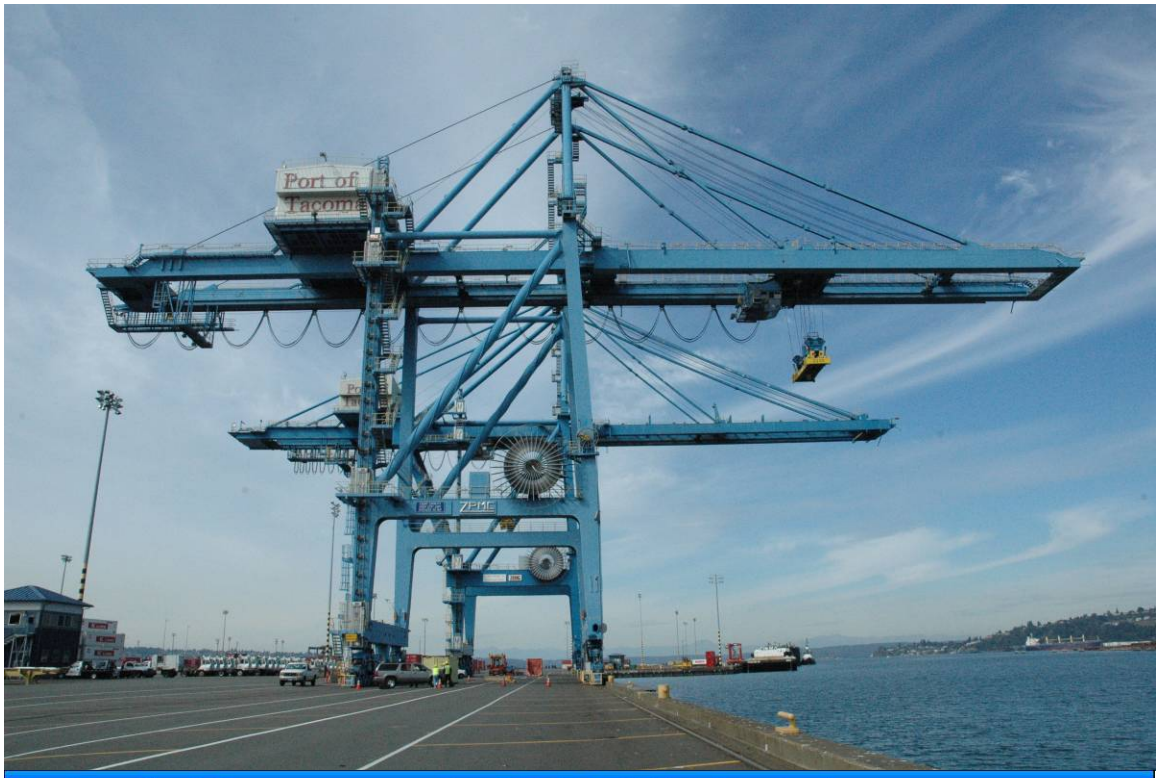


Figure A-5. Position 5, Unloaded



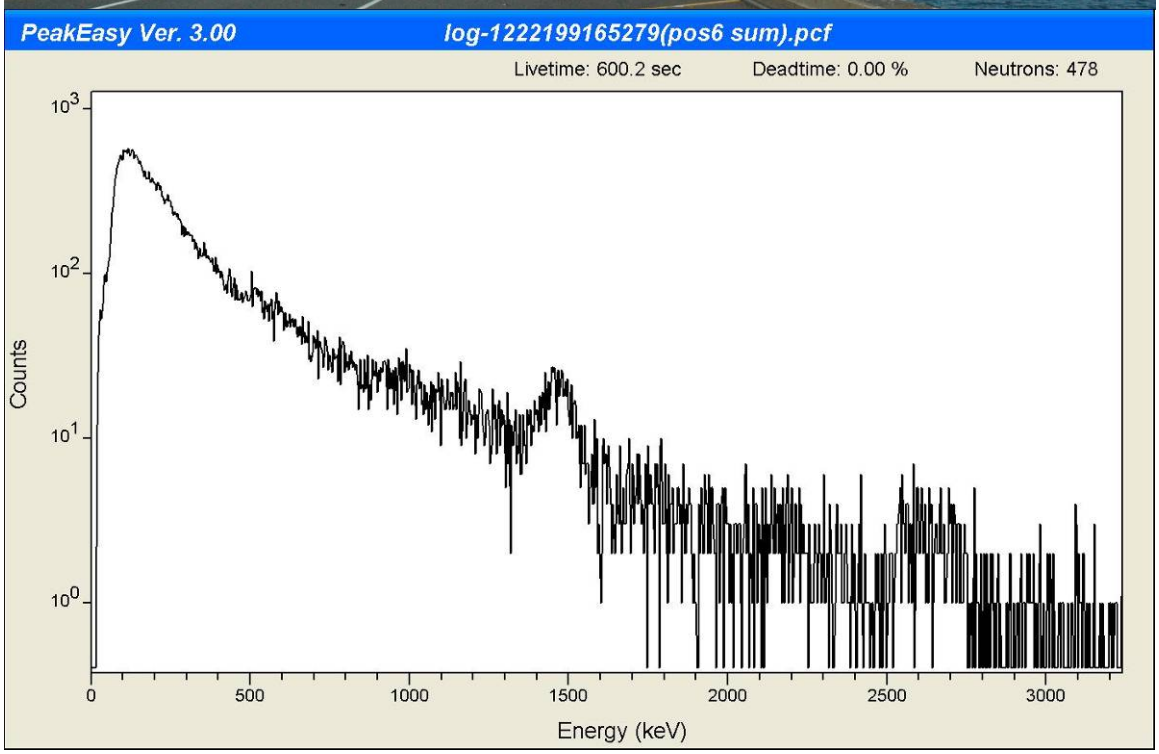
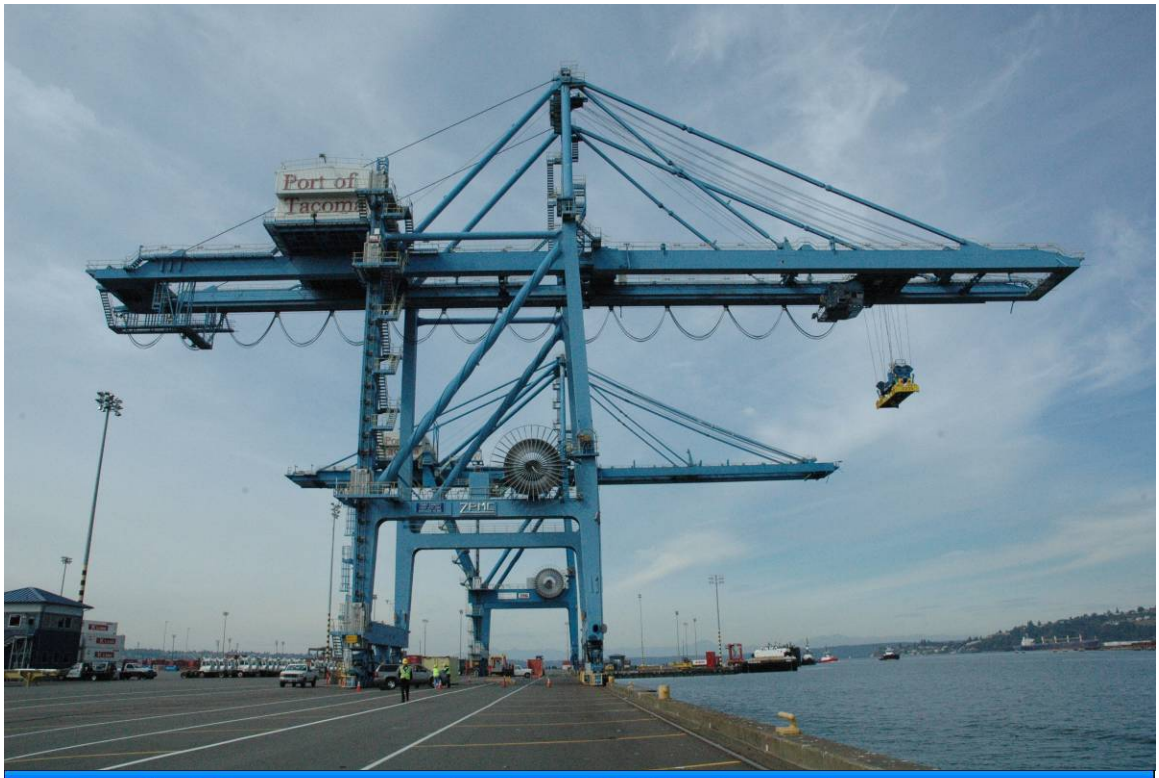


Figure A-6. Position 6, Unloaded



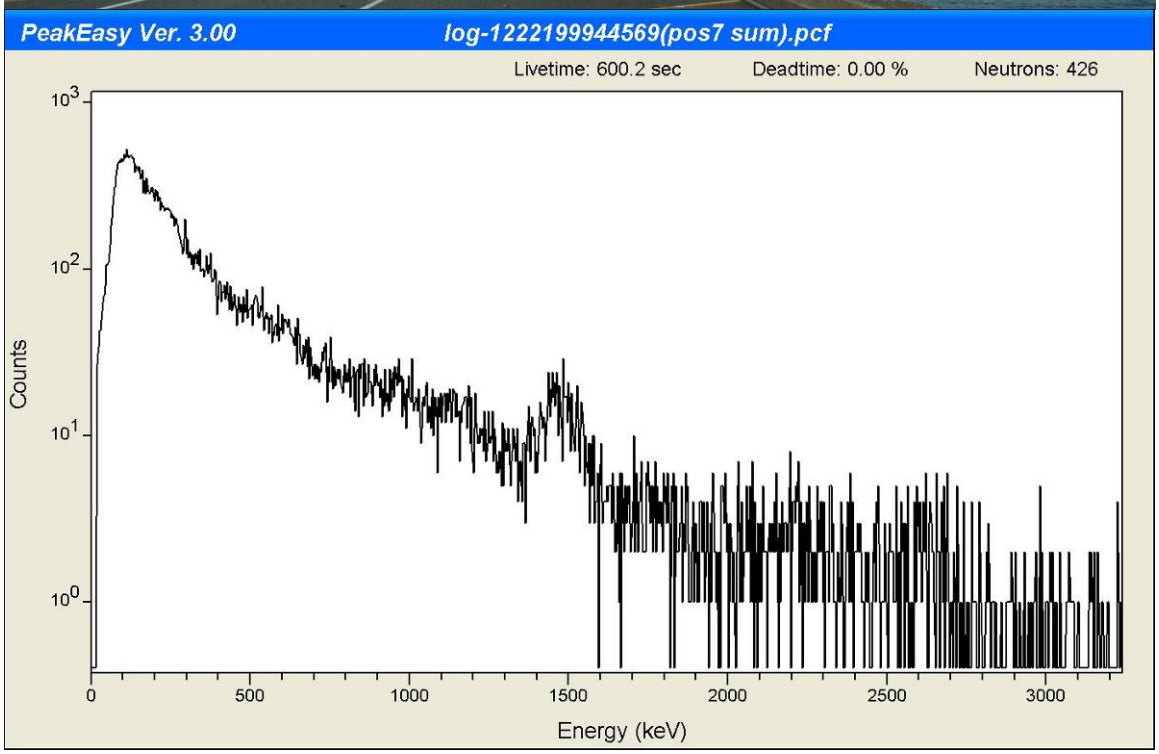
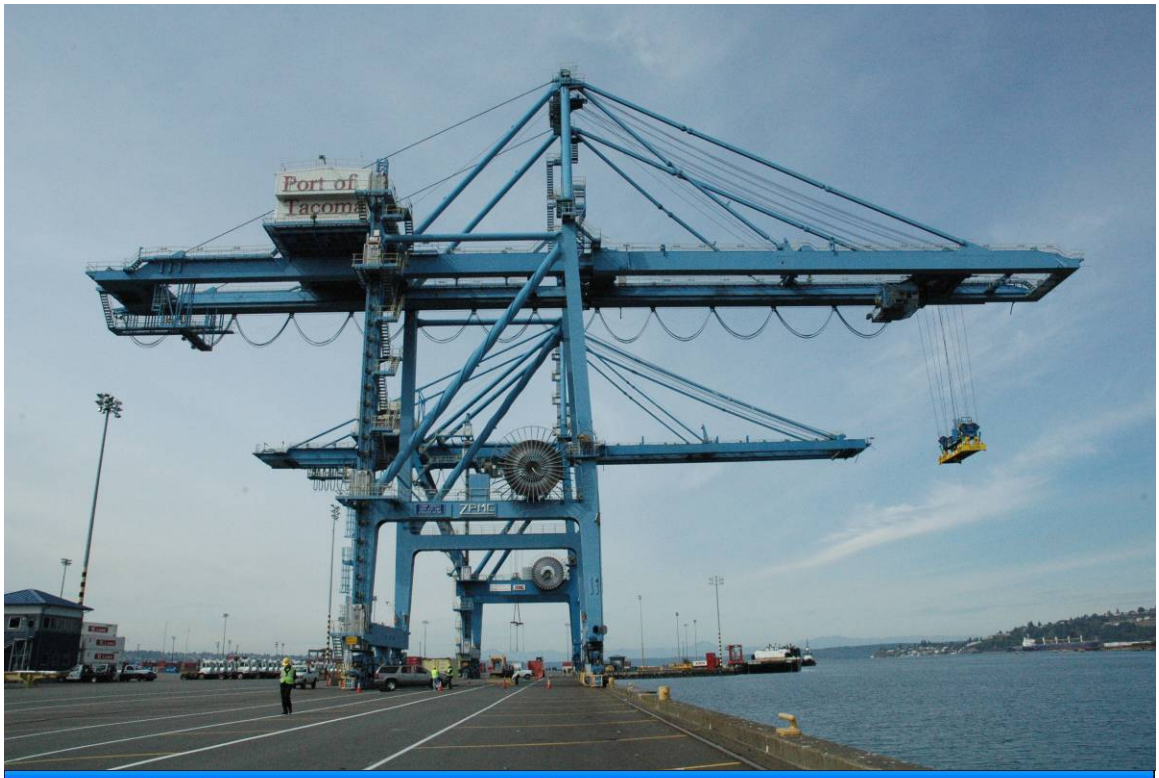


Figure A-7. Position 7, Unloaded



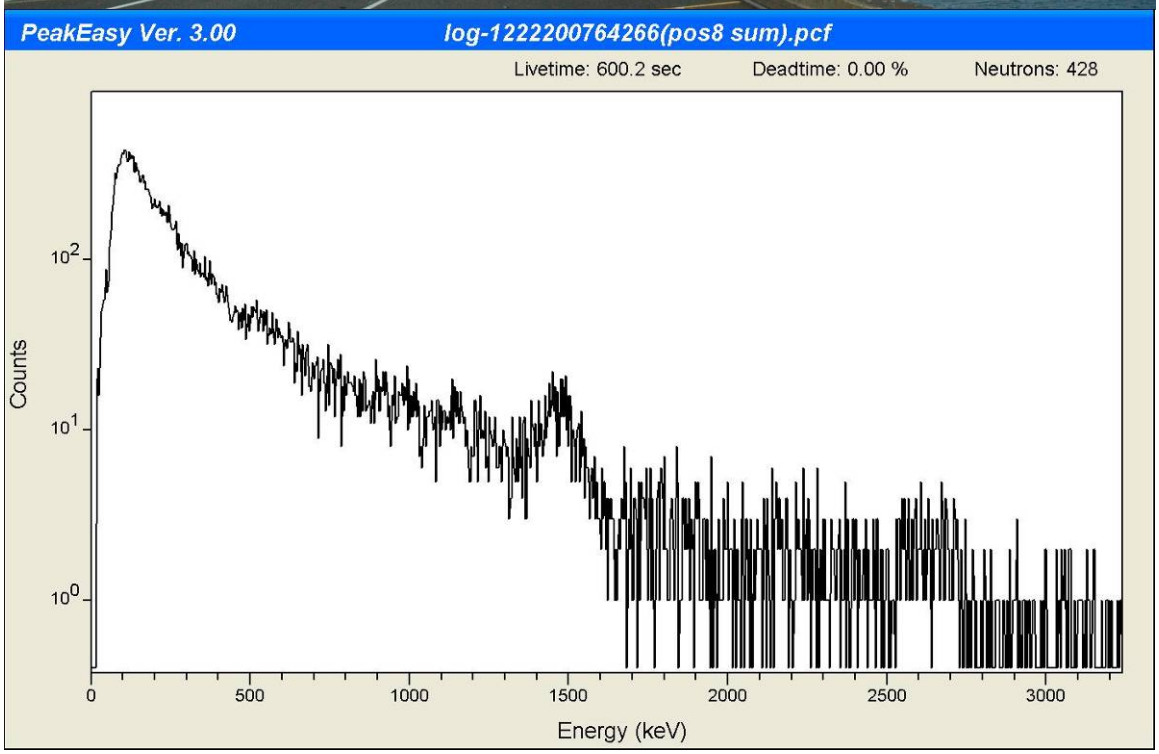


Figure A-8. Position 8, Unloaded

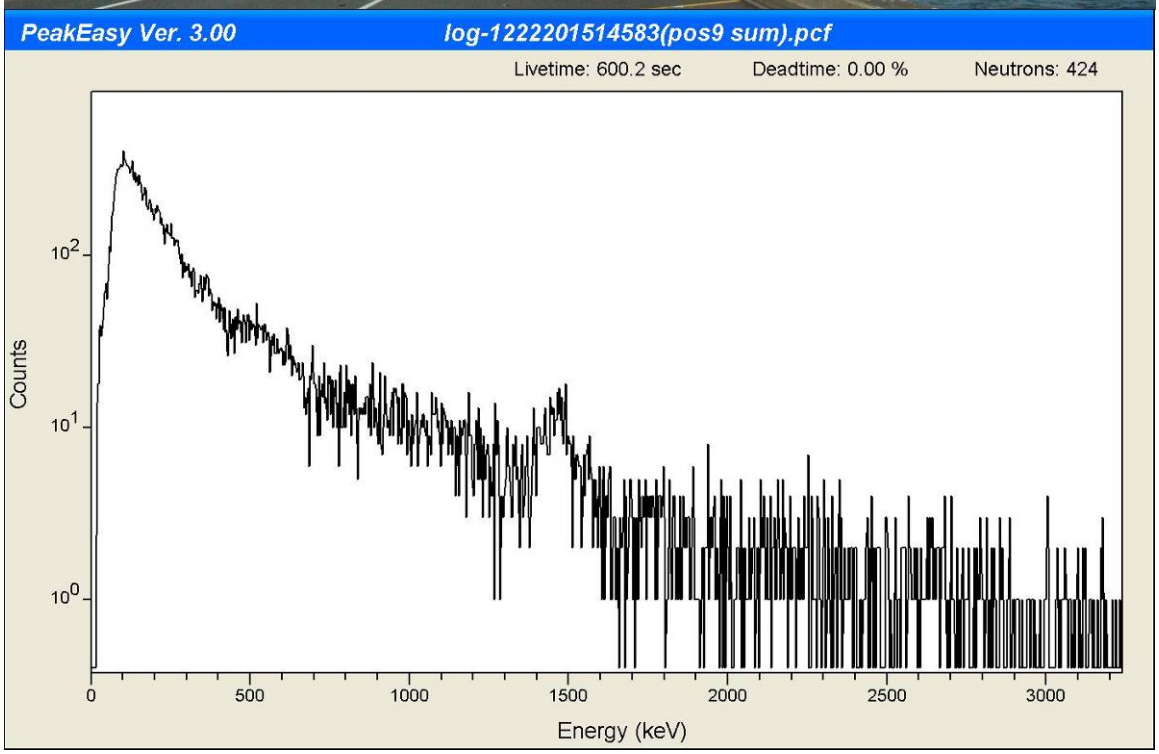
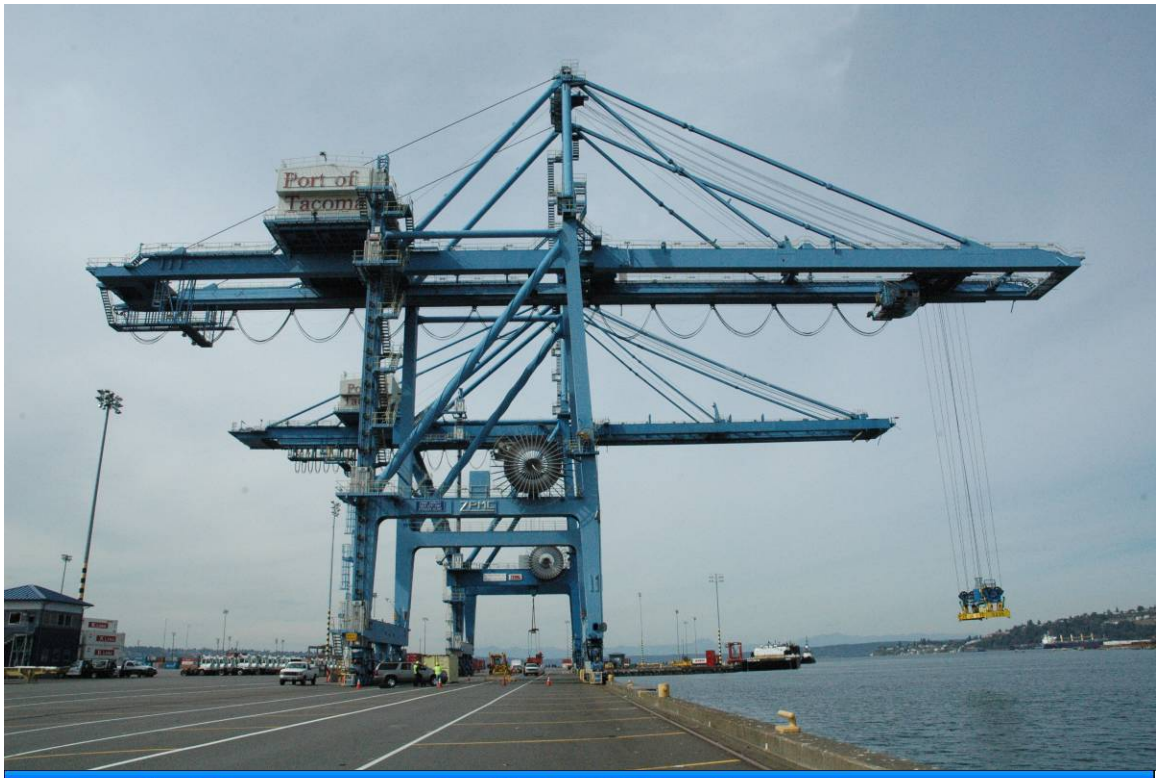


Figure A-9. Position 9, Unloaded



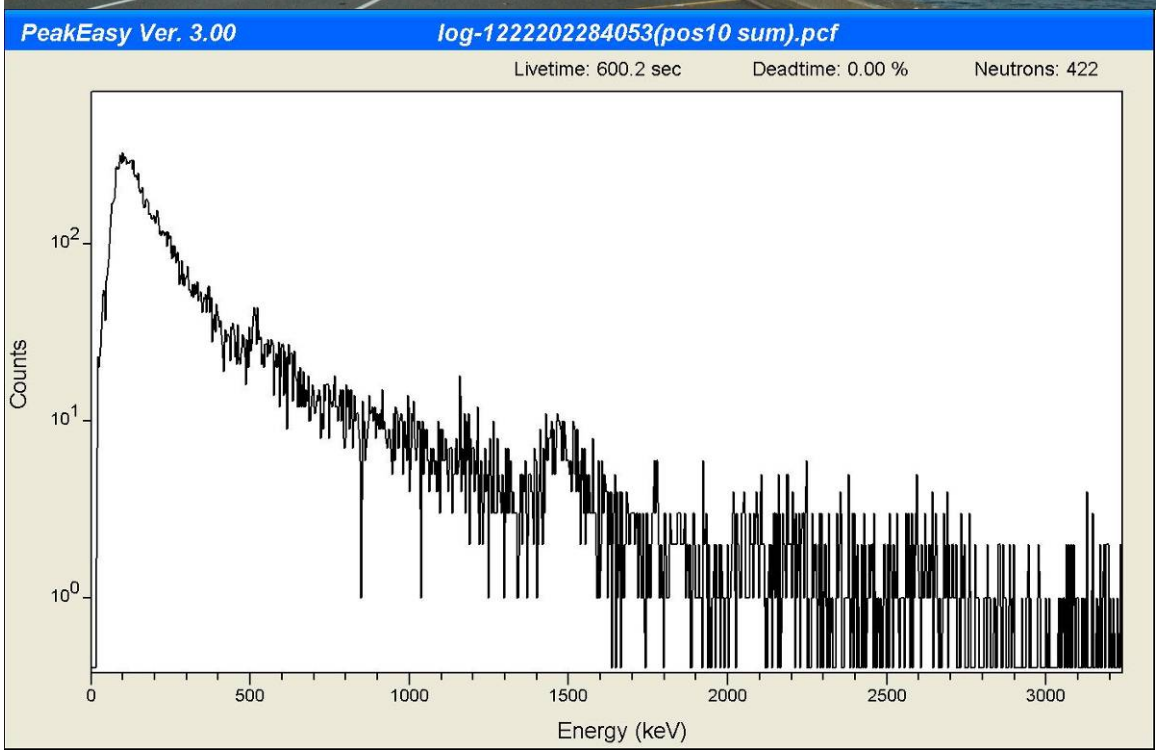
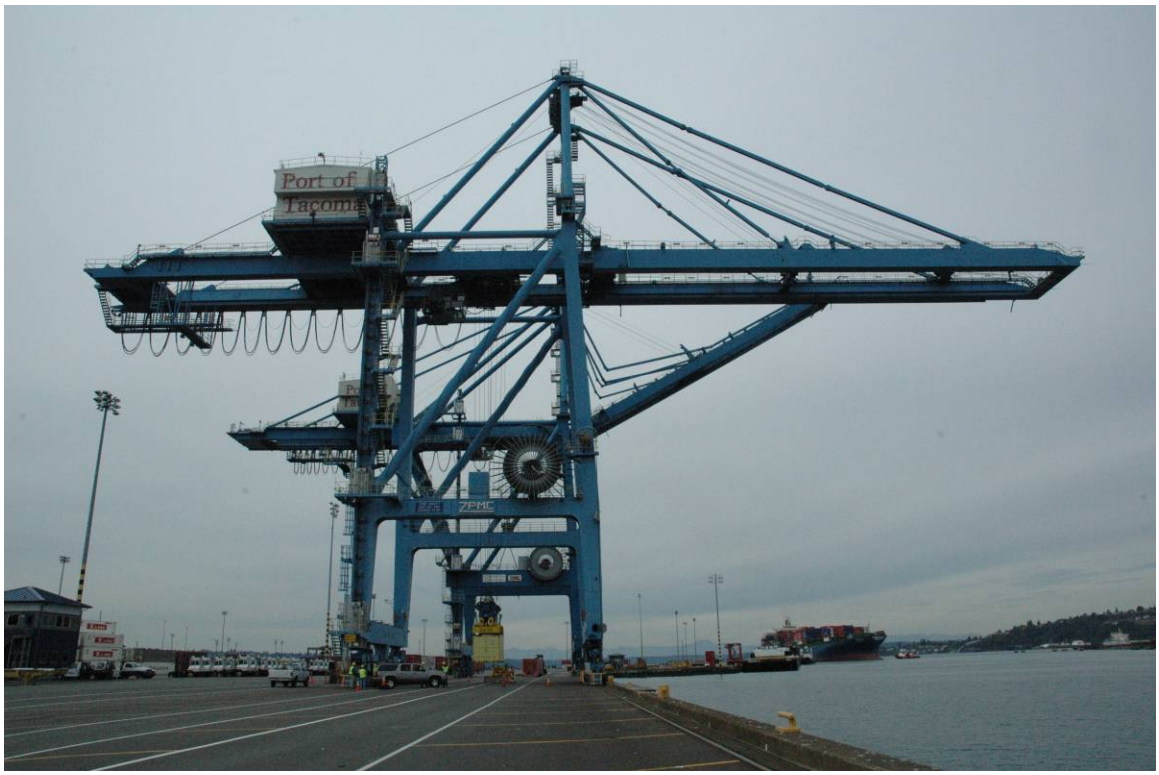


Figure A-10. Position 10, Unloaded

Appendix B: Static Tests, Empty Container



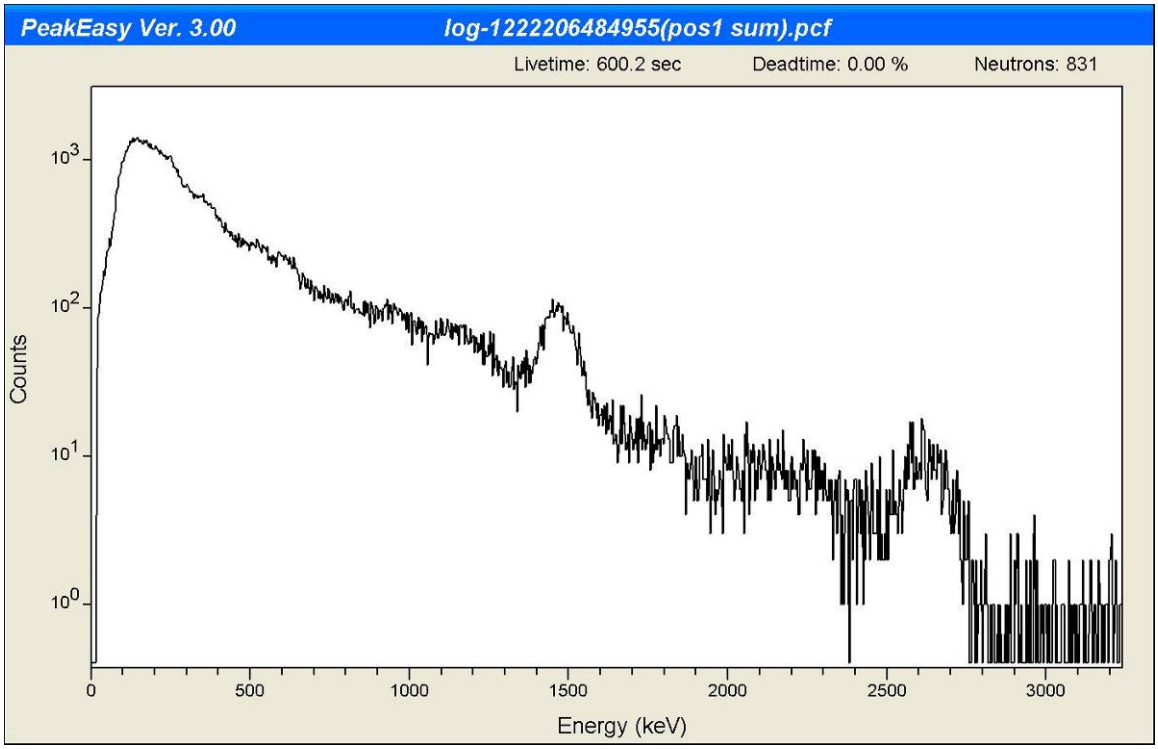


Figure B-1. Position 1, Empty Container

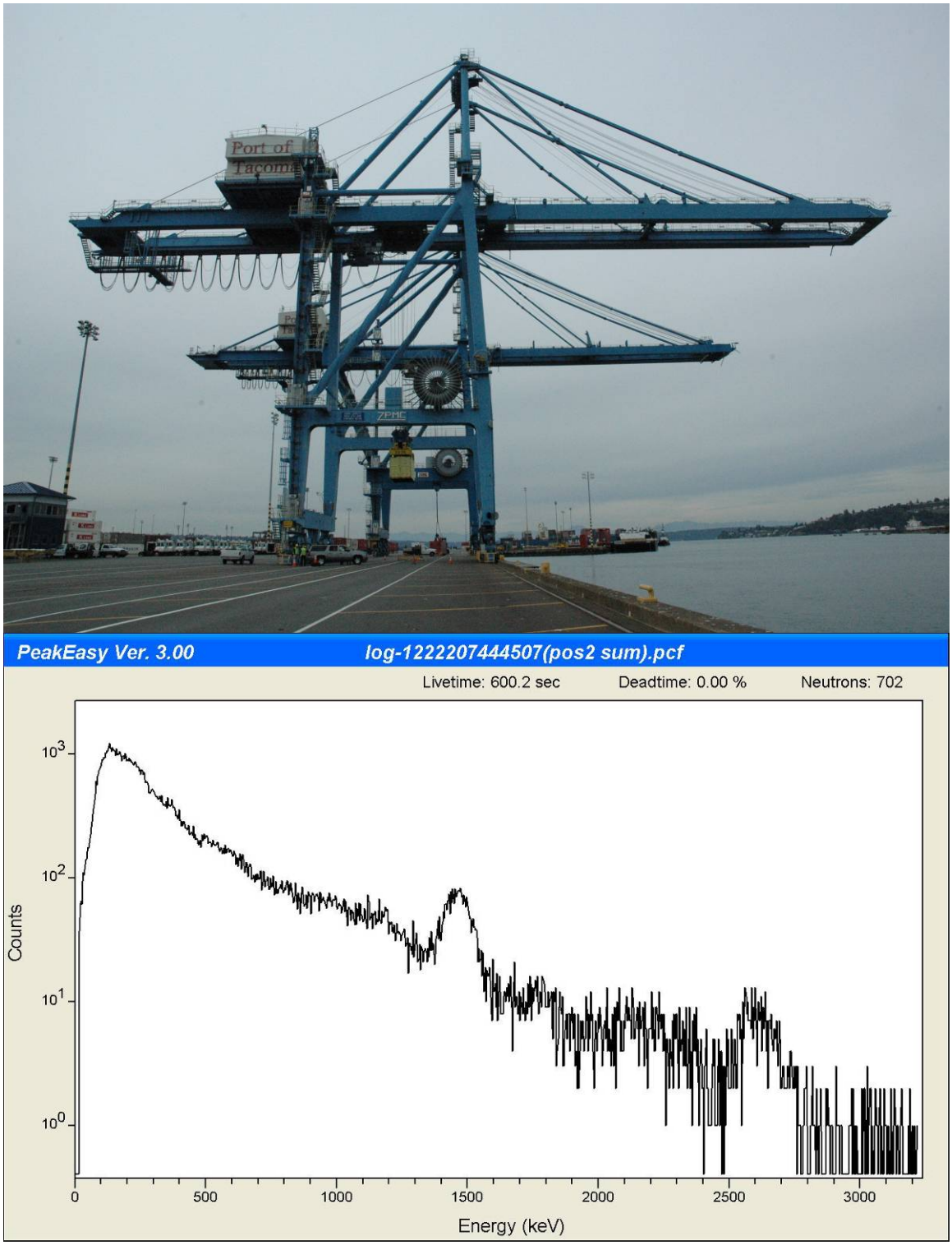


Figure B-2. Position 2, Empty Container

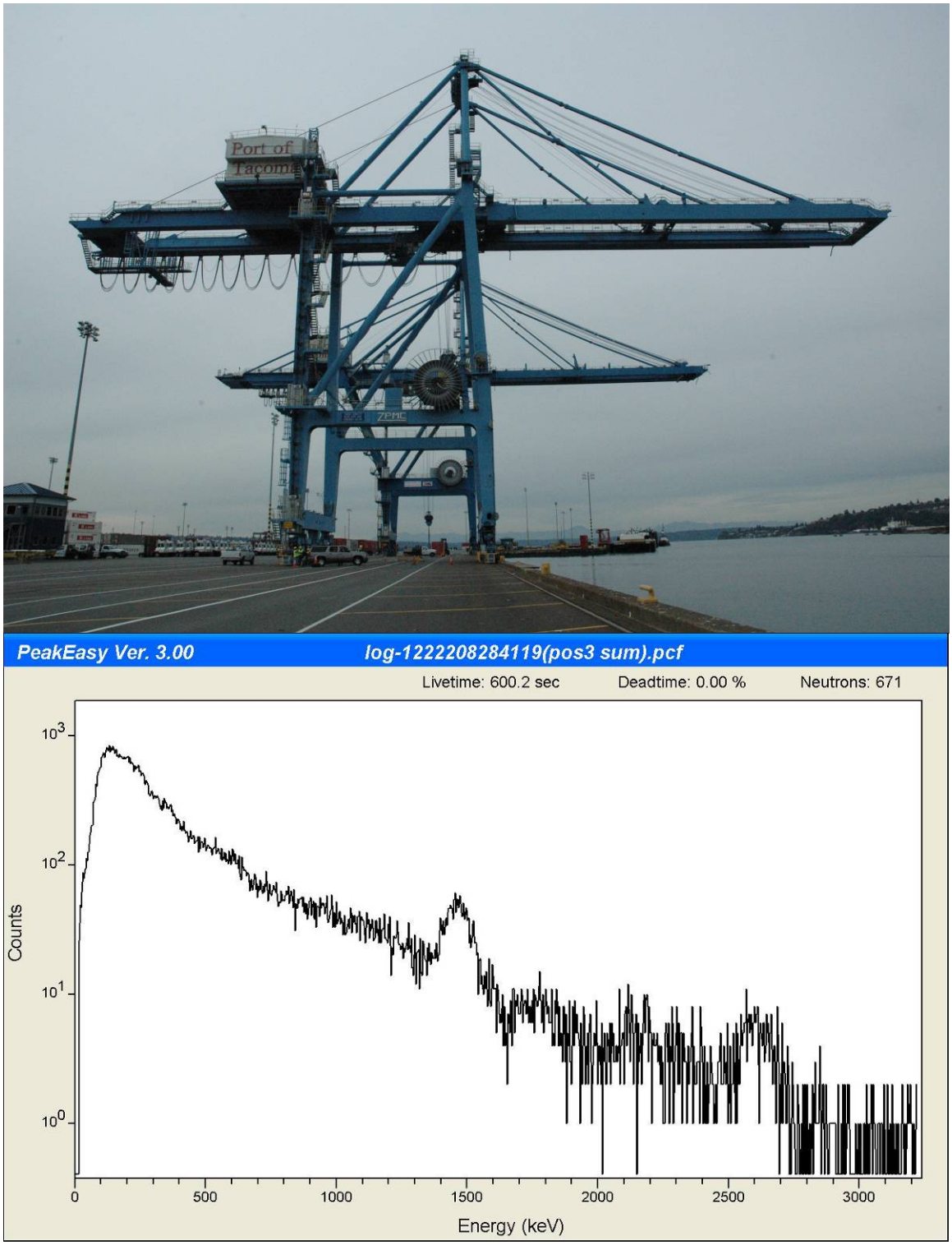


Figure B-3. Position 3, Empty Container

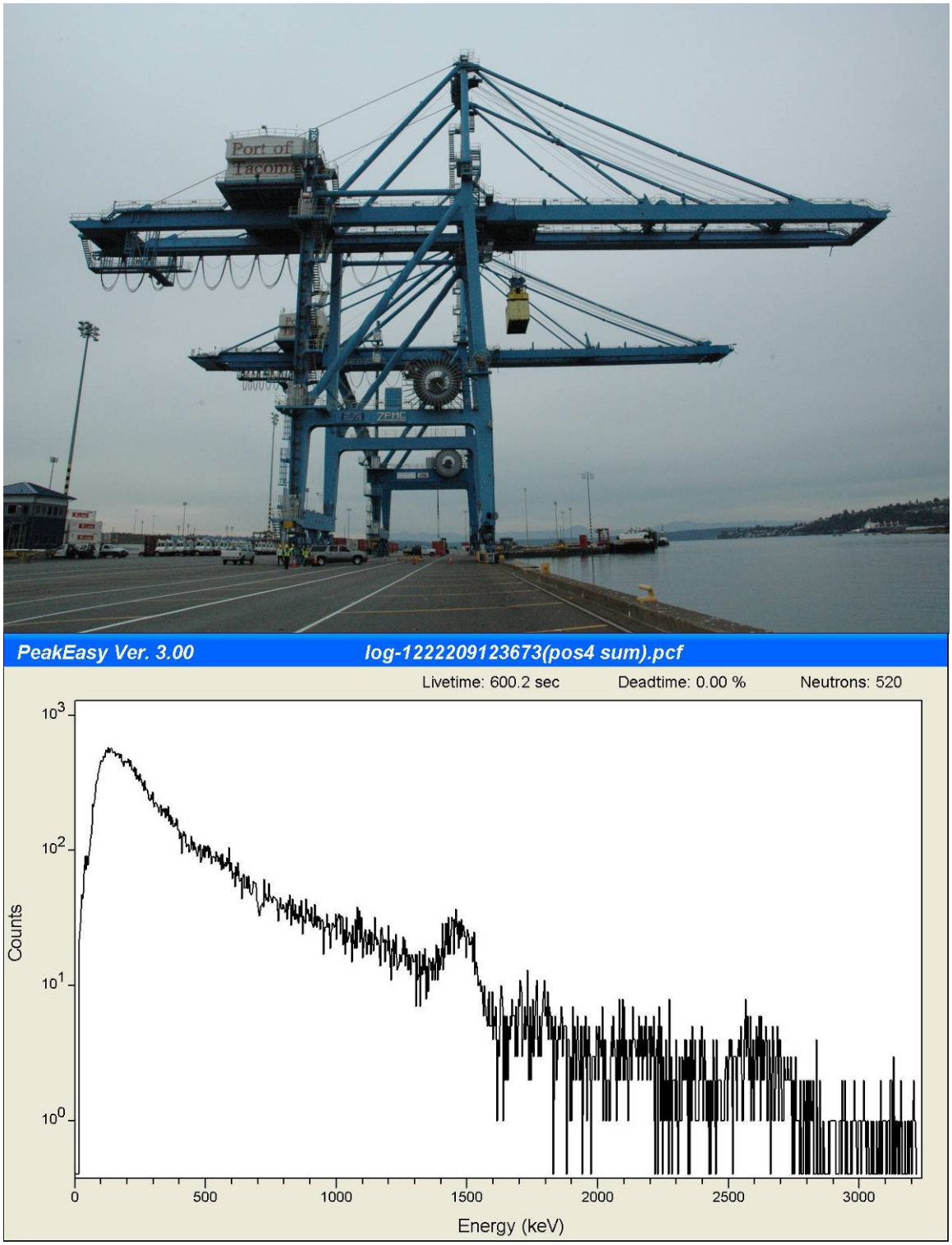


Figure B-4. Position 4, Empty Container

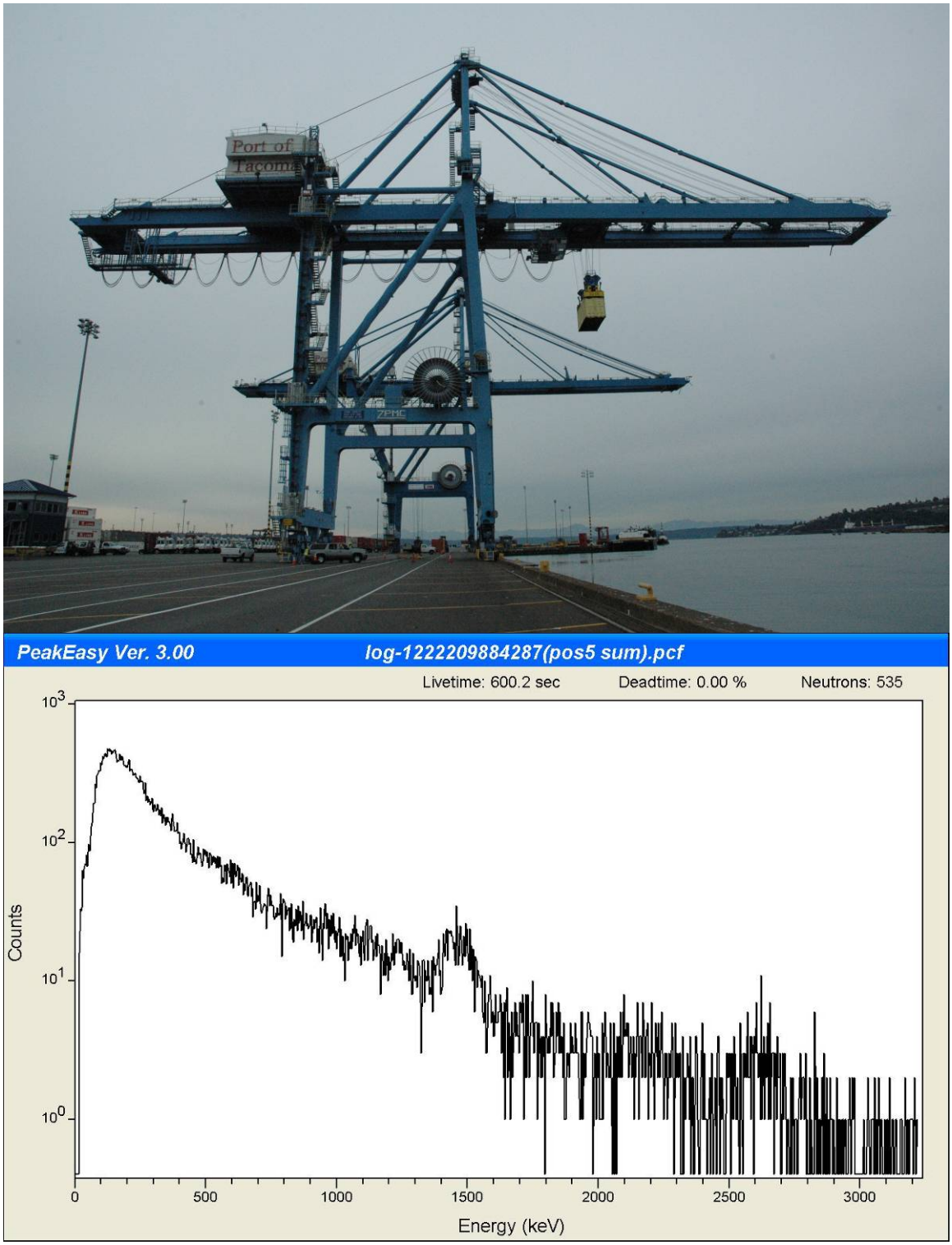


Figure B-5. Position 5, Empty Container

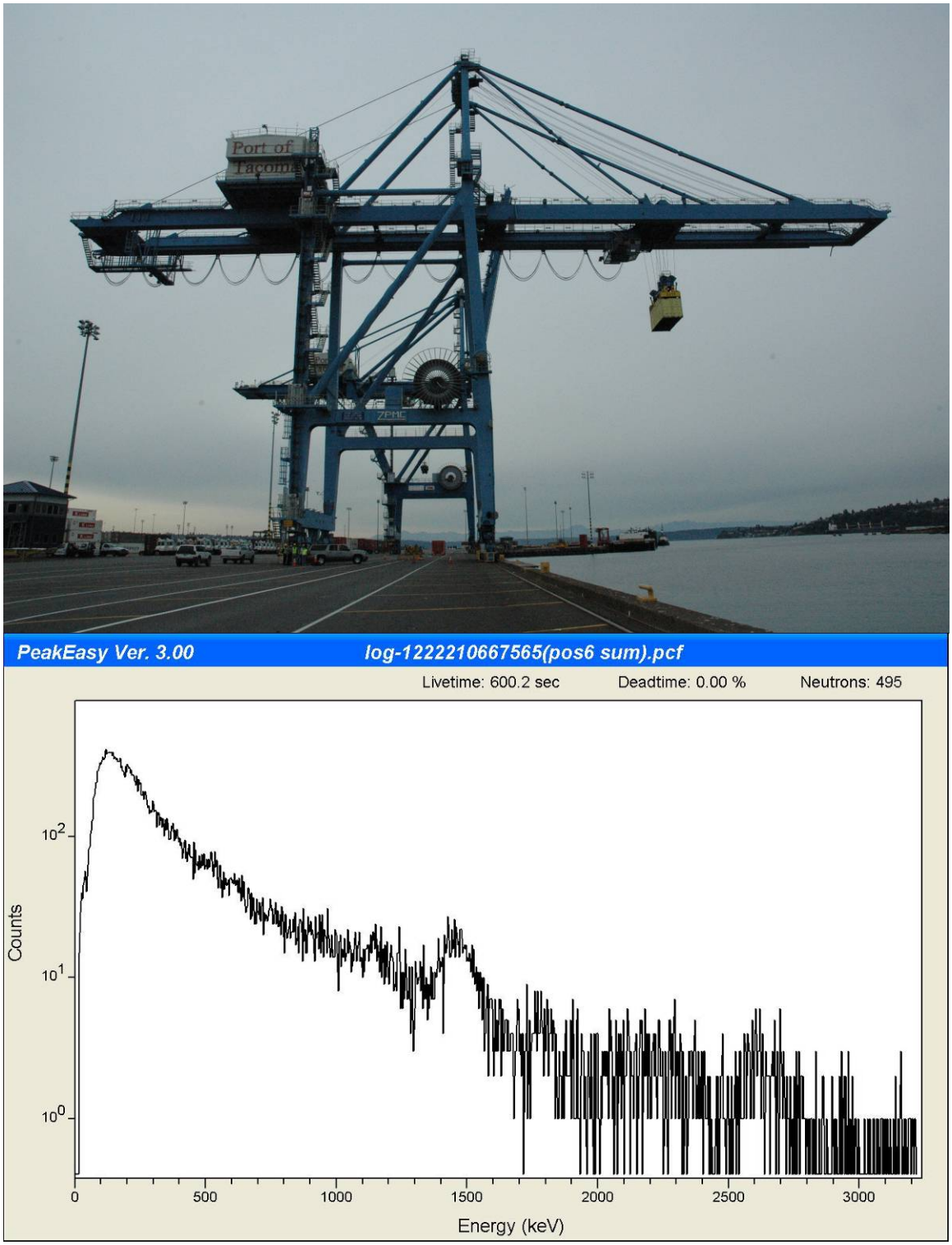


Figure B-6. Position 6, Empty Container

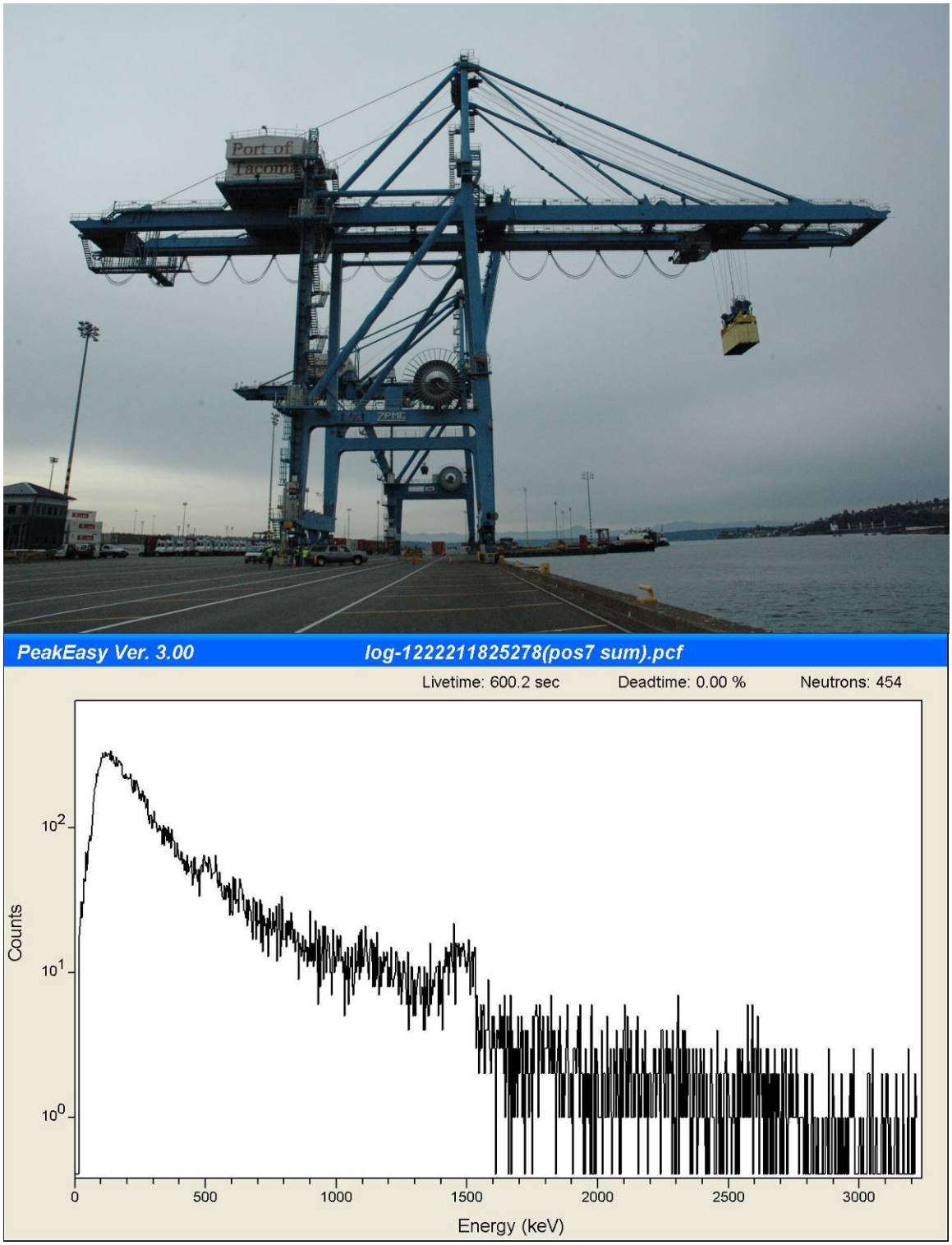


Figure B-7. Position 7, Empty Container

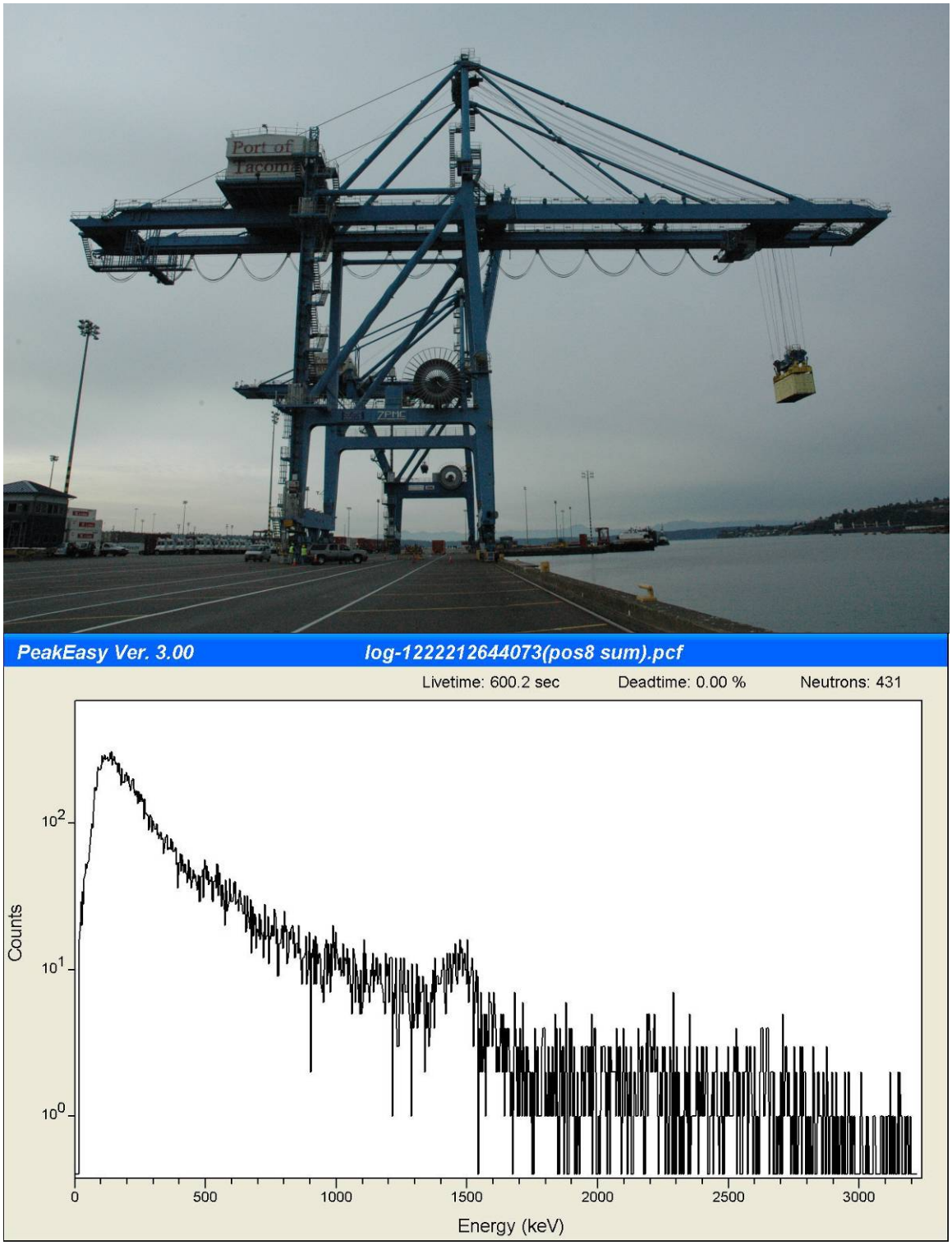


Figure B-8. Position 8, Empty Container

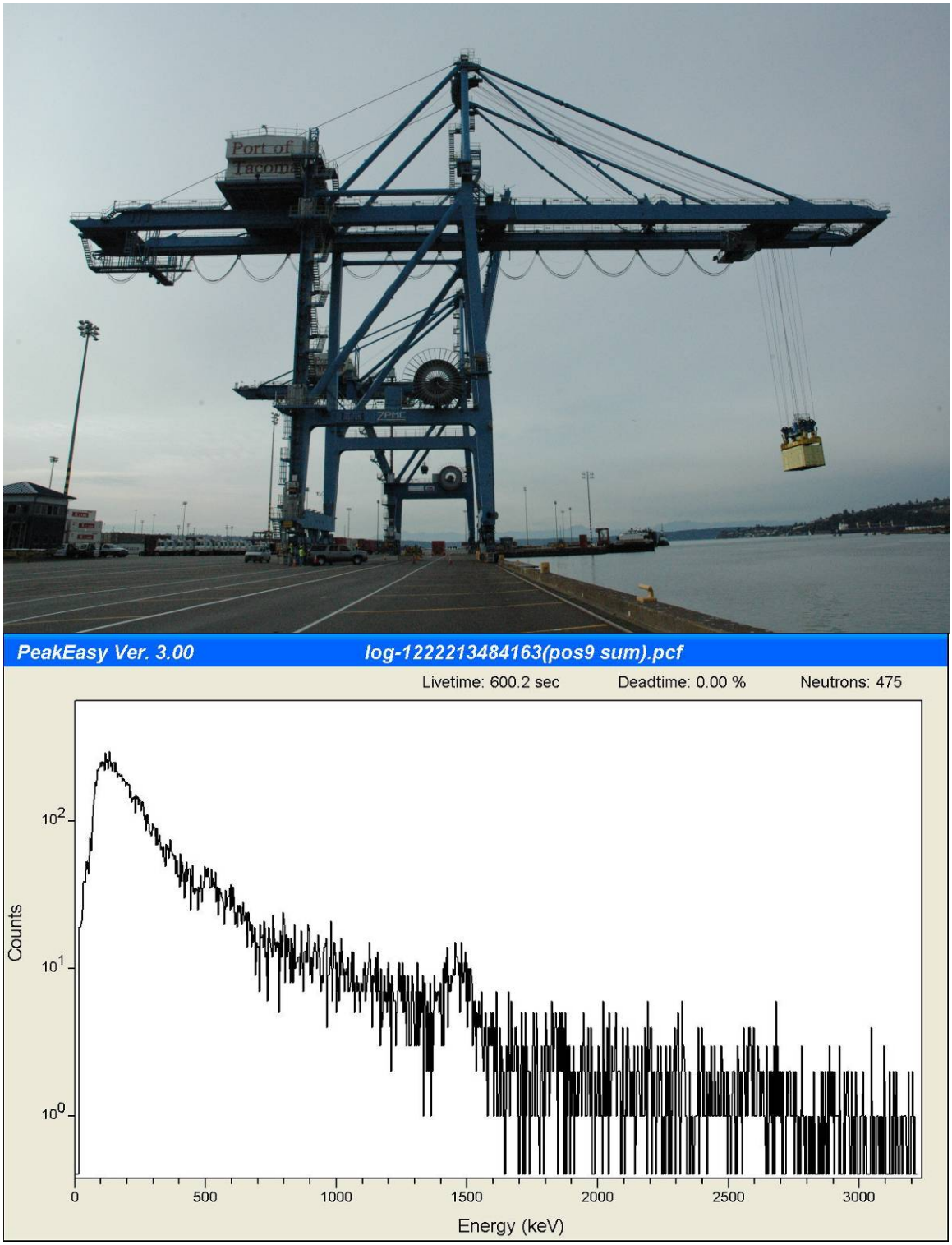


Figure B-9. Position 9, Empty Container

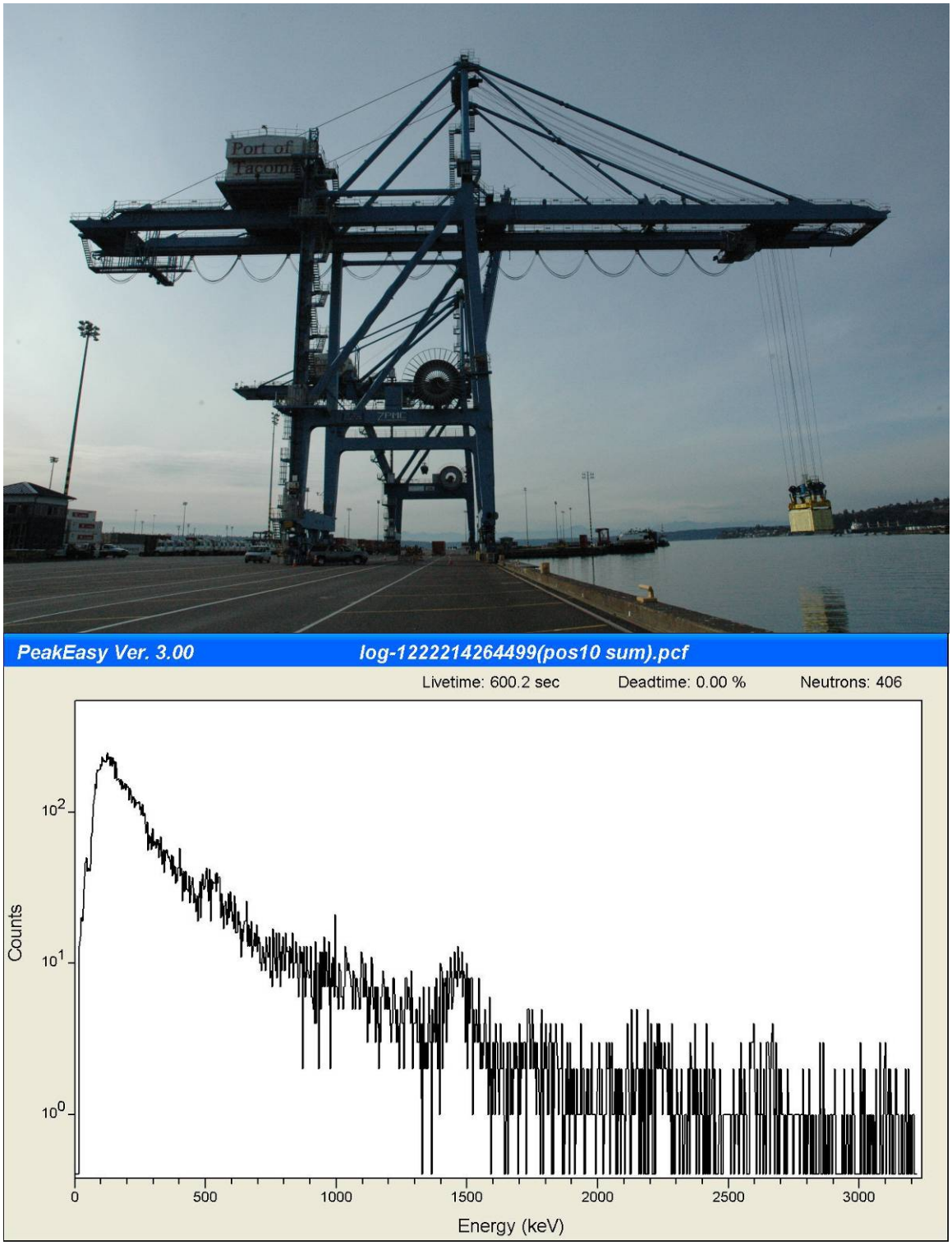


Figure B-10. Position 10, Empty Container

Appendix C: Data Tabulation

	Unloaded				Empty Container			
Position	Gamma counts	Gamma (cps)	Neutron Counts	Neutron (cps)	Gamma counts	Gamma (cps)	Neutron Counts	Neutron (cps)
1	185380	308.93	824	1.37	149168	248.54	831	1.38
2	148194	246.92	771	1.28	115522	192.48	702	1.17
3	104677	174.41	715	1.19	82622	137.66	671	1.12
4	72236	120.36	576	0.96	55906	93.15	520	0.87
5	58689	97.79	518	0.86	45853	76.4	535	0.89
6	47635	79.86	478	0.80	38267	63.76	495	0.82
7	39278	65.44	426	0.71	30342	50.55	454	0.76
8	32175	53.61	428	0.71	25764	42.93	431	0.72
9	26368	43.93	424	0.71	23166	38.6	475	0.79
10	21270	35.44	422	0.70	19276	32.12	406	0.68

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