SAND99-1842C

International Remote Monitoring Project
Embalse Nuclear Power Station, Argentina
Embalse Remote Monitoring System

Sigfried L. Schneider, Donnie D. Glidewell, Sandia National Laboratories (SNL)

Anibal Bonino, Autoridad Regulatoria Nuclear (ARN), Argentina

Gene Bosler, David Mercer, Los Alamos National Laboratory (LANL)

Curt Maxey, Oak Ridge National Laboratory (ORNL)

Jaromir Vones, Guy Martelle, International Atomic Energy Agency (IAEA)

James Busse, Department of Energy (DOE)

Steve Kadner, Mike White, Aquila Technologies Group (a Canberra Co.) (ATG)

Luis Rovere, Brazilian-Argentine Agency for Accounting and Control of Nuclear Material (ABACC)

Abstract

The Autoridad Regulatoria Nuclear of Argentina (ARN), the International Atomic Energy Agency (IAEA), ABACC, the United States Department of Energy, and the US Support Program POTAS, cooperated in the development of a Remote Monitoring System for nuclear nonproliferation efforts. This system was installed at the Embalse Nuclear Power Station last year to evaluate the feasibility of using radiation sensors in monitoring the transfer of spent fuel from the spent fuel pond to dry storage. The key element in this process is to maintain continuity of knowledge throughout the entire transfer process. This project evaluated the fundamental design and implementation of the Remote Monitoring System in its application to regional and international safeguard efficiency. New technology has been developed to enhance the design of the system to include storage capability on board sensor platforms. This evaluation has led to design enhancements that will assure that no data loss will occur during loss of RF transmission of the sensors.

INTRODUCTION

BACKGROUND The Embalse Remote Monitoring System (ERMS) was a joint development effort between ARN of Argentina and the U.S Department of Energy national laboratories. During the development, the IAEA was included in the final design process. This collaborative effort was to design and develop a remote monitoring system to monitor spent fuel transfers to dry storage silos. Radiation data, complemented by C/S (video images) data, provide the continuity of knowledge necessary for the IAEA inspectors to assure the integrity of the transfer process. The 1st

DISCLAIMER

DISCLAIMER

generation ERMS system of radiation sensors and a video camera was installed in April 1998. Evaluation of the system identified modifications, which would enhance the performance of the system. This paper provides an overview of the modifications made to upgrade this system with new and improved technology.

SYSTEM UPGRADE

Hardware – The 1st generation ERMS consisted of 6 gamma radiation sensors and 1 neutron sensor. These sensors are identified as D1 – D6. D1, D2, and D4-D6 are individual gamma sensors and D3 is a gamma/neutron sensor package. These sensors are integrated into an Echelon Local Operating Network (LON), which is connected to an IAEA MOS/MUX server for data collection and distribution

Evaluation of sensor data from the 1st generation ERMS identified deficiencies in the quality of the data. The deficiencies were identified as follows: D1, the sensor that monitors the transfer of spent fuel bundles in the spent fuel pond, does not provide enough data to verify that the bundles being transferred are spent fuel, and data from the RF sensor, D2, D4, D5, and D6, may be missing due to the RF transmission being interrupted or blocked. No modifications to sensor D3 were identified.

Following the analysis of the data for D1, the conclusion reached by the IAEA, determined that a gross gamma signal was insufficient to verify that bundles transferred into Flask #1 were spent fuel. Additional sensor data is required to provide the necessary confidence that only spent fuel bundles are transferred into the flask. Two acceptable options were identified by the IAEA. (1) Provide a combined neutron/gamma signal for each bundle, or (2) Provide a gamma spectroscopy verification of each bundle. Los Alamos and ARN explored both options. Geometric constraints and Embalse facility concerns about operational delays make the neutron/gamma option impractical. In April and May 1999 Los Alamos and ARN conducted tests of an underwater spectroscopy system based on a Cadmium-Zinc-Telluride (CdZnTe) sensor to identify the ^{137}Cs signature of spent fuel. The prototype system was mounted between the turning table and transfer flask, and viewed each bundle as it passed overhead during normal loading operations. Operational delays are minimal, and the results suggest that this is a very effective method for bundle verification.

Evaluation of data from all RF sensors and a review of the operation of the sensors indicated that data could be lost should the RF communication between sensor and receiver be blocked. The IAEA stated the each sensor must be capable of storing all data when communications is disrupted and forwarding the data once communication is reestablished. The current technology used in the ERMS would not meet this requirement. The possibility to modify the current electronics to include this capability was investigated. The investigation revealed that it would not be cost effective to modify the current system. Sandia identified a development effort underway within Sandia to design state of the art Electronic Sensor Platforms (ESP). Discussions revealed that the sensor platform being developed, with some modification, would meet the requirements to store and forward data. This was the course taken to upgrade the ERMS to meet IAEA requirements.
The modification of D1 is the responsibility of LANL and ARN. D2, D4 and the silo sensors, D5 & D6, were to be replaced with the new Electronic Sensor Platforms. The original LON network remains with only some software changes to allow the integration of the new ESP's and ESPI's.

Software – The original ERMS included the Sandia developed Modular Integrated Monitoring System (MIMS) software, which was used to populate a database for sensor data. This software program was based on a16-bit Access database application which became slower and slower as the database stored more and more data. This was very inefficient for large amounts of data processing. The IAEA placed a requirement on SNL to upgrade this system to a 32-bit application, which was compatible with Windows NT 4.0. Cost analysis to upgrade the MIMS software concluded that it would be more cost effective to employ the new SNL developed Material Monitoring System software which is based on the 32-bit SQL server database. A member of the MMS software development team upgraded the original MIMS software to the new MMS software in April 1999. Additional information on the operation of the MMS software can be obtained from Joseph Domico or Larry Desonier of SNL.

Modifying the hardware to store and forward data identified new software requirements. Data sent in the original system was time and date stamped after the Echelon node received it. In the upgraded system each sensor that stores data must time and date stamp each data message, as soon as it is recorded from the sensor by the ESP, before it is transmitted to the Electronic Sensor Platform Interrogator (ESPI). In addition each message sent must be authenticated. The software development plan identified all aspects of event and state of health (SOH) messages that the new sensor platform would be sending. Time, date and authentication were designed into the message structure for each sensor platform. To authenticate the data Sandia decided to use the TEA authentication algorithm. This is a private key algorithm and was originally developed in the UK as an encryption algorithm. Sandia modified the algorithm to use as an authentication algorithm and to speed up key distribution.

When sensor data communication occurs, only authenticated messages are accepted by the ESPI and passed on to the LON network. In the event that a message is not authenticated the ESPI will generate an authentication error message and the ESP will continue to send the message until it is authenticated. The interval at which a message is sent to the ESPI is programmable and when the message is not authenticated it is stored until the next interval occurs for transmitting data.

All RF sensor platforms are equipped with software programmable thresholds. These thresholds are set to activate when this level is exceeded. D2 and D4 are programmed to record a SOH message every 20 minutes and are programmed so that when the threshold is exceeded the sensor will start recording event messages every 3 minutes. The sensor will continue to record at the 3-minute interval until the radiation level falls below the threshold level at which time the 20 minute SOH interval will take over.

Sensors D2 and D4 were designed to monitor a gross gamma signal through the heavily shielded walls of the transportation flasks. Sensor D2 is mounted on the lid of Flask #1, which moves between the spent fuel pond and the welding hot cell. This sensor must be waterproof since the lid is lowered into the water and onto the flask. While the lid is submerged, no RF transmission of the radiation signal is possible but after the lid has settled onto the flask radiation data is being gathered and stored in memory. After the lid breaks the surface of the water, RF communication is established and all the stored data is transmitted to the ESPI. This sensor is also heavily shielded to protect the electronics within the sensor housing when the lid is raised and the basket is moved from the flask to the welding table. During this transfer, the radiation level inside the welding hot cell may reach into the kRad range. Each ESPI is connected to the Echelon LON network. Sensor D4 monitors the radiation signal on Flask #2, which transports the welded baskets from the hot cell area to the silo field. Sensor D4 is similar in functionality to D2 in that it also records SOH messages at a 20-minute interval and also records event data at a 3-minute interval once the threshold is exceeded. The difference with this sensor is that it is neither waterproof nor heavily shielded.

Sensors D5 – D8 were designed to fit inside a 2-inch diameter instrumentation tube. Each Embalse silo has two instrumentation tubes, which are used to verify the contents of the silo after they are full. The original system allowed for one sensor per silo instrumentation tube. The new sensor platforms allow two sensors to be installed in each instrumentation tube. These sensors are installed in a staggered mode to provide directional data during transfers. Software design for these sensors is different from sensors D2 and D4. As each basket is lowered into the silo the background radiation level increases. To prevent this sensor from constantly transmitting messages at a 2-second interval the program must be capable of adjusting to the changes in the background level of radiation. As each basket is inserted into the silo a new background level must be established and the threshold raised to prevent the sensor from sending data at an accelerated mode. Sensors D5 – D8 are programmed so that when the threshold is exceeded, the sensor changes from SOH mode to event mode and transmits messages at a 2-second interval. This mode is maintained for 2 minutes while the radiation data is transmitted to the ESPI. After two minutes, the software starts checking for a new background level. If the radiation level is relatively constant the sensor reverts to the SOH mode, but if the signal is still changing, event data continues for 2 additional minutes before the background level is checked again. This ensures that the sensor provides all event data. SOH messages are send at 6-hour intervals for all silo sensors.

Installation - The upgraded system was designed to have each Electronic Sensor Platform (ESP) communicate with a dedicated Electronic Sensor Platform Interrogator (ESPI). The ESPI's were mounted in a configuration, which minimized the work required to change out the original system receivers. The ESPI's were mounted on plates, which allowed the original housings to be used for the new electronics. ARN personnel were instrumental in accomplishing the removal of the original system hardware and the installation of the new hardware. The silo sensor ESPI hardware was replaced first so that the silo sensors could be tested. Oak Ridge prepared each silo sensor according to the installation plan. The first two silo sensors were installed to monitor the transfer and test the communication between the ESP and ESPI. Silo sensor data were being received during the transfer of the baskets. After the silo was completely full, the silo sensors had to be moved to the next silo.

The ESPI's for D2 and D4 were installed in the hot cell room. The ESP's for D2 and D4 were setup, tested and installed on the appropriate flask. Some minor problems were encountered but resolved and the system was operational at the end of the installation. The final phase of the installation was to test the entire system. All sensors and ESPI's were functional and the data were collected and transferred to the MOS/MUX server. These data were then transferred to the server at Ezeiza.

Data Evaluation – Data received from the Embalse server during the fuel transfer campaign is currently being evaluated and preliminary results indicate that the system is functioning according to design. Because the new D1 sensor was not available, data from the original sensor platform was collected. These data were similar to the data collected in May 1998. With the use of the new sensor platform, data reported must be converted to radiation units and analyzed. The following figures show some of the sensor data in graphic form and the typical radiation profiles. The data on the X-axis is the 3-digit Julian date and Greenwich time.

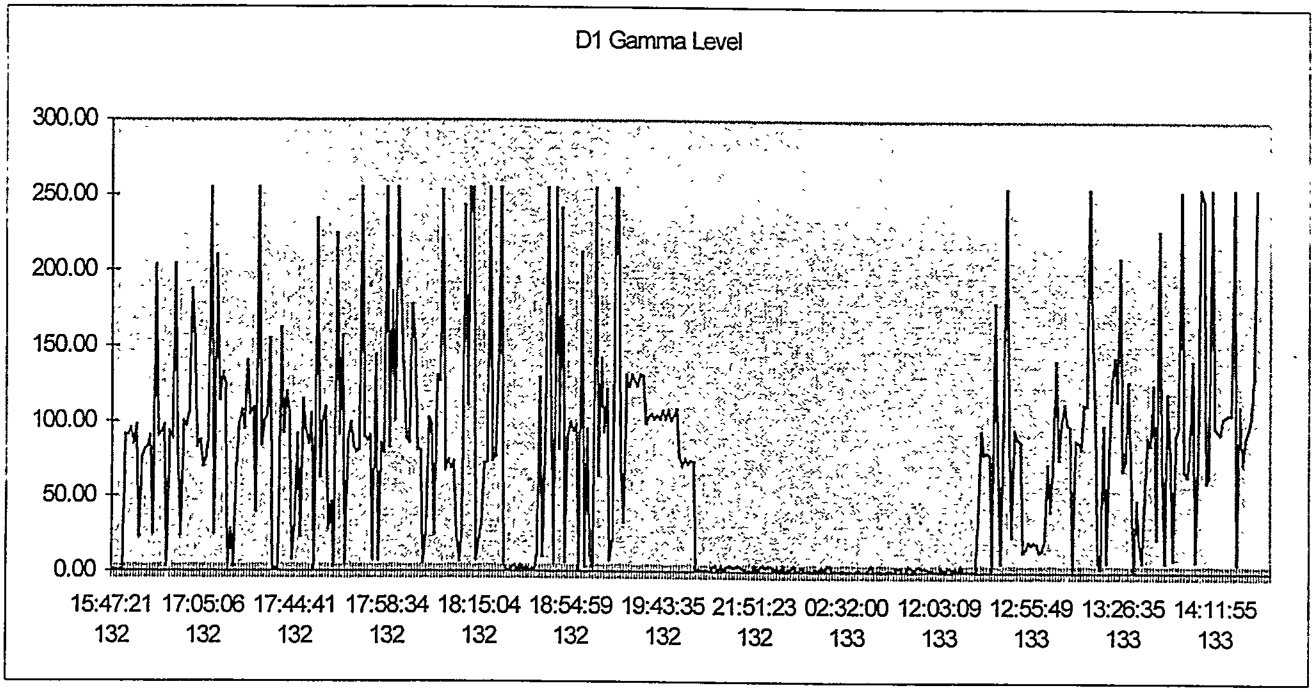

Figure 1. Data from sensor D1 show individual bundles being transferred from the turning table to the flask. This data will change once the new D1 is in place and gamma spectroscopy is used to verify spent fuel bundles.

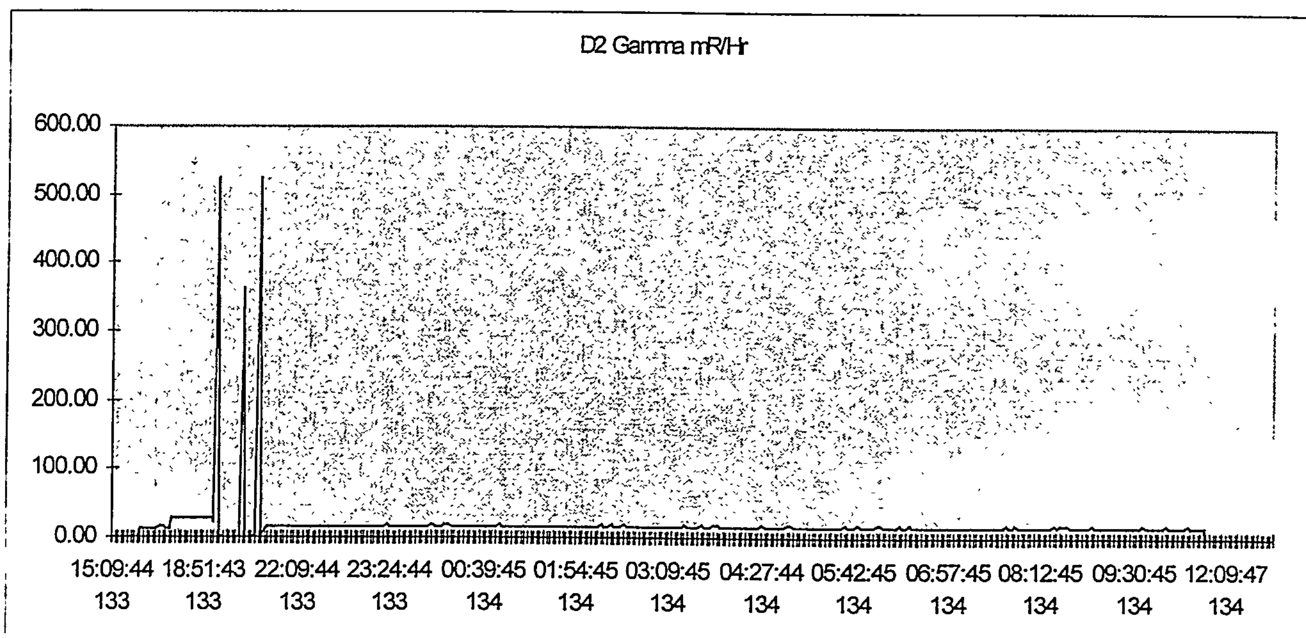

Figure 2. Data from sensor D2 show the flask transfer from the spent fuel pond into the welding hot cell. The large spikes occur when the basket of bundles is transferred from the flask to the welding table. In this graph the basket was removed from the flask and later put back into the flask due to welding problem.

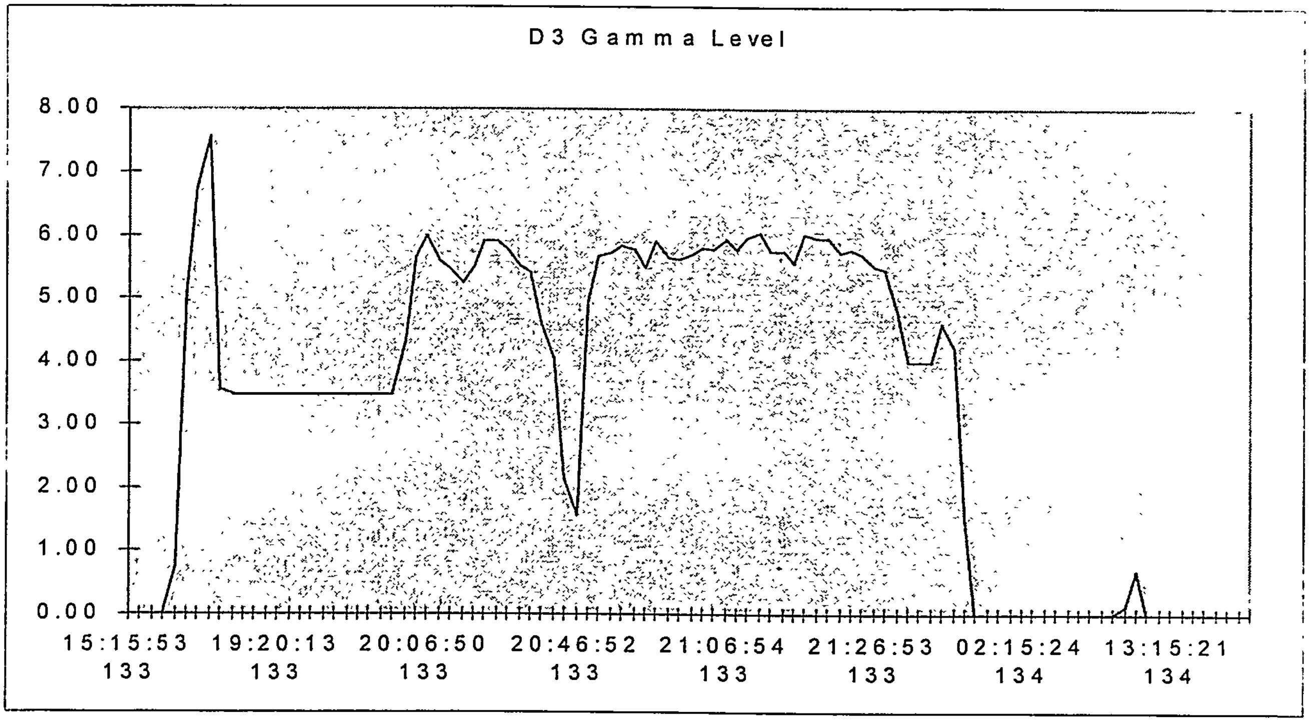

Figure 3. Data from sensor D3 show the gamma signal inside the welding hot cell. The graph shows the lid being raised from the flask, the basket being raised and moved to the welding table, and then the transfer of the welded basket into flask #2.

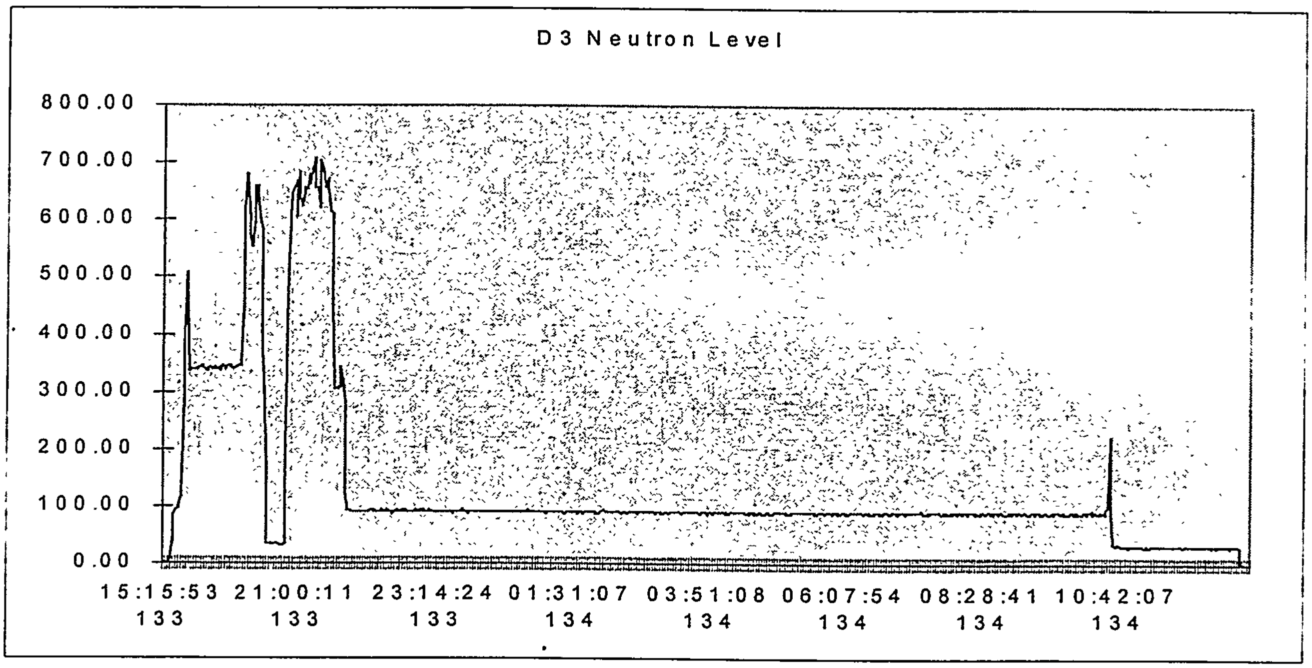

Figure 4. Data from sensor D3 show the neutron signal as flask #1 is transferred from the spent fuel pond into the welding hot cell, as the lid is raised, as the basket is moved from flask #1 to the welding table and as the basket is raised into flask#2. A short time later the basket is lowered back into the welding hot cell for a short time, raised into the flask again and transferred to the silo.

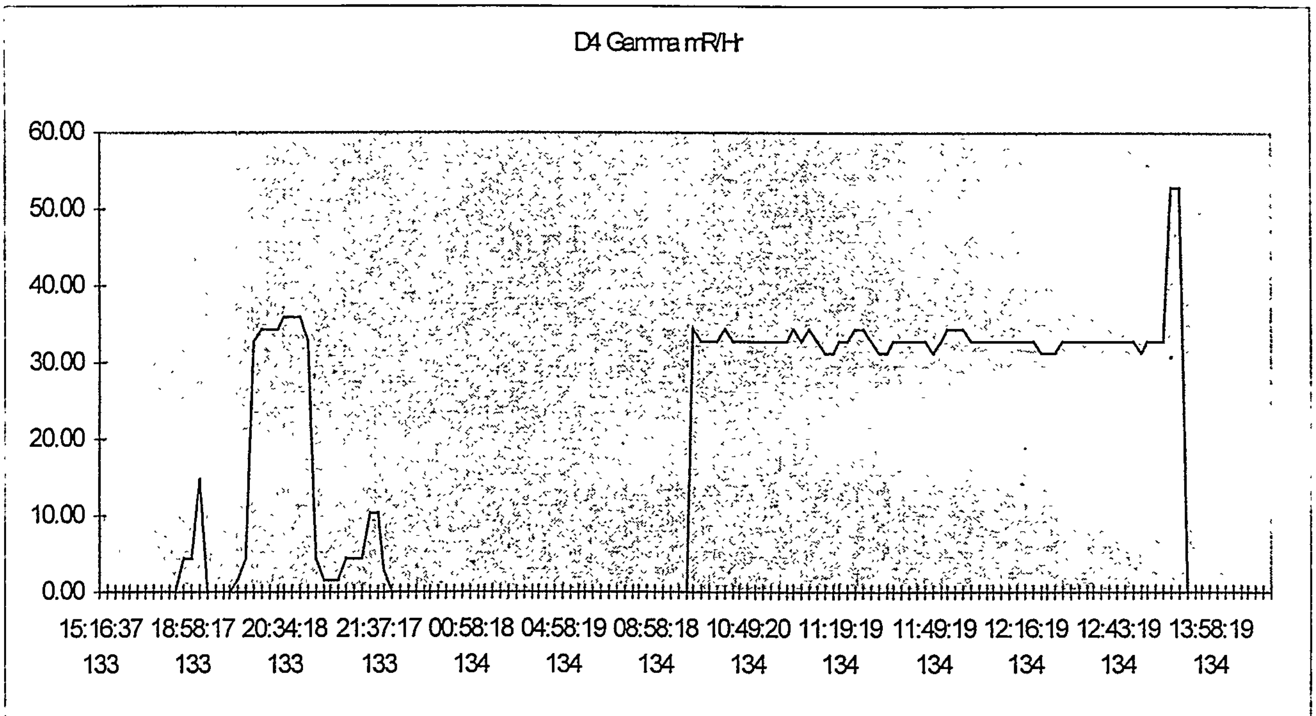

Figure 5. Data from sensor D4 show the welded basket being raised into flask #2, then lowered into the welding hot cell and the following day raised into the flask again and then transported to the silo field, and lowered into the silo.

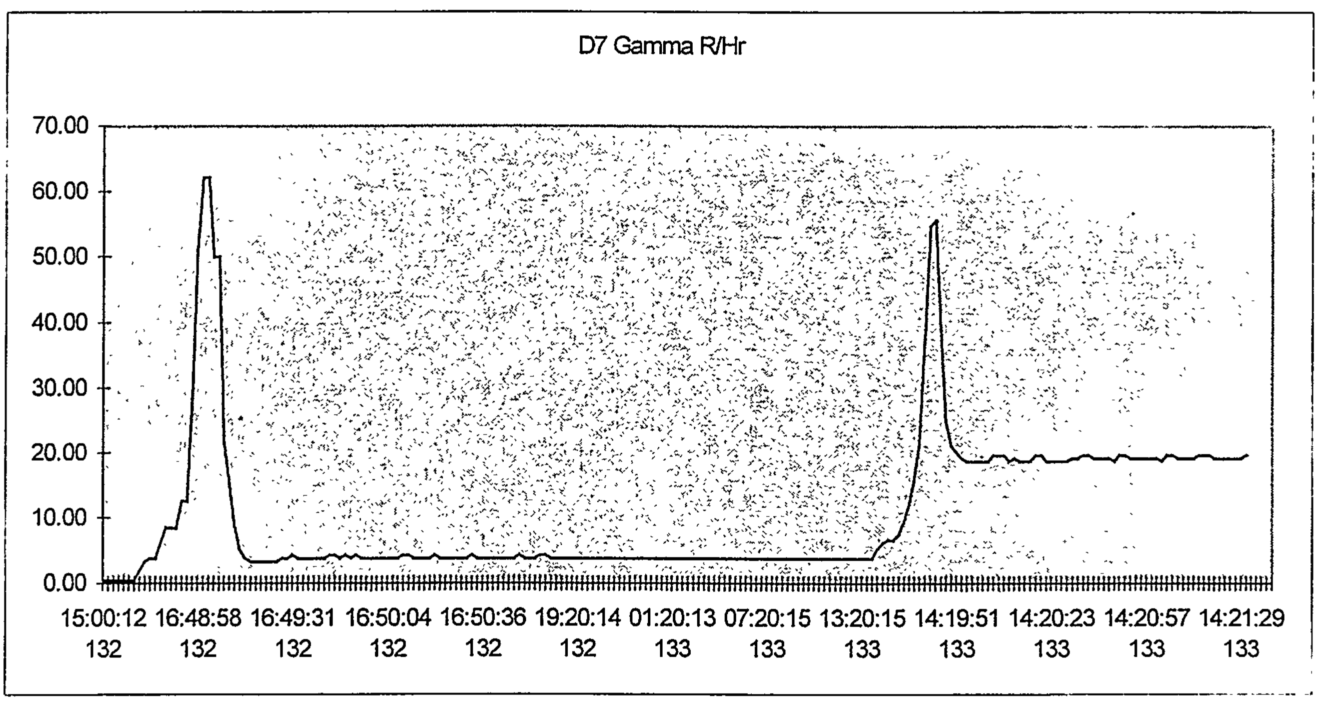

Figure 6. Data from sensor D7 show the insertion of two spent fuel baskets into the silo. Each signal peak is a basket being lowered past the sensor. As indicated in the body of the text, the background level increases as each basket is placed into the silo.

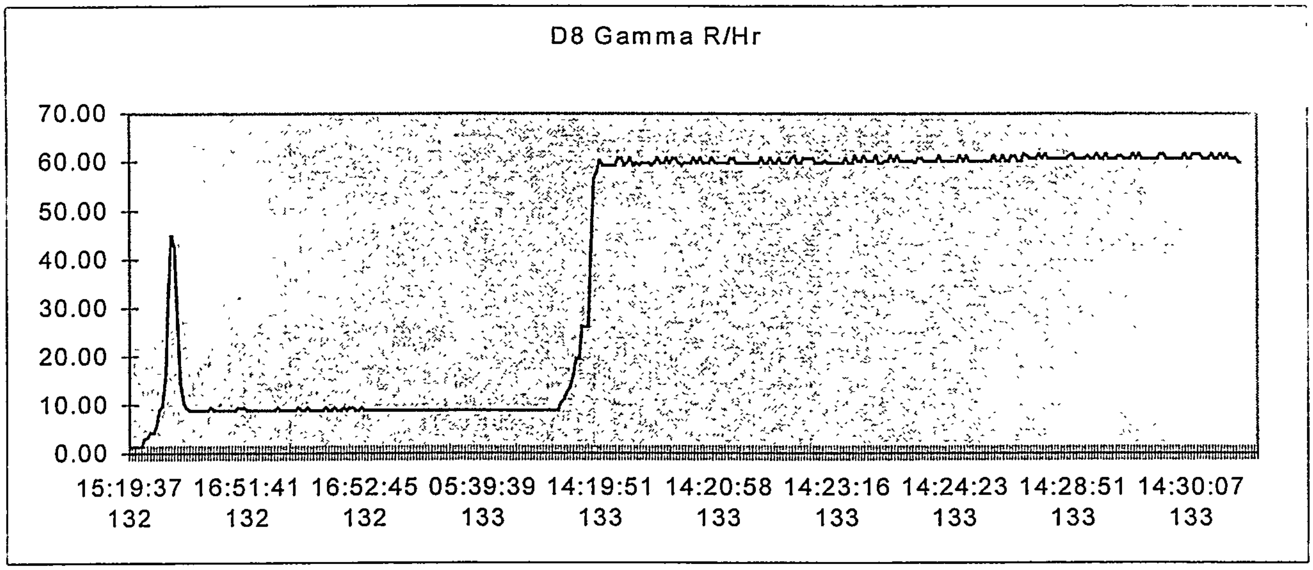

Figure 7. Data from sensor D8 show the insertion of two baskets. The first signal peak is of basket #7 being lowered into the silo passed the sensor. The last signal increase on the graph shows the insertion of basket #8 into the silo and because the sensor is in the same location as basket #8 the signal does not decrease. This sensor is positioned about 50 cm lower than sensor D7 and is in the same location as basket #8.

Conclusion

Further upgrades to the ERM system have been planned and will be incorporated in future spent fuel transfer campaigns. The upgrades that were made to the ERMS during the April – May 1999 spent fuel transfer campaign enhanced the system's performance and met the IAEA requirements. Data that were collected and have been analyzed indicates that the system is performing up to everyone's expectations.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.