Title:
INTERNATIONAL REMOTE MONITORING PROJECT
ARGENTINA NUCLEAR POWER STATION REMOTE
MONITORING SYSTEM

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Abstract
A remote monitoring system, designed to monitor spent fuel transfers from wet to dry storage, was installed at the Embalse Nuclear Power Station at Embalse, Argentina. The system consists of 6 gamma and one neutron radiation sensors. Five gamma sensors utilize RF transmission to communicate with Echelon nodes connected to a Local Operating Network (LON). One gamma and one neutron sensor are hardwired to the LON network. Each sensor Echelon node is bound to a single Datalogger that stores data until it receives an acquisition command to download to the Data Acquisition Software (DASW) database. The data from the Datalogger are transferred and stored in the Data Acquisition Software database, which resides on the IAEA MOS-MUX server. At a pre-determined interval, data from the DASW database are converted into Excel files and transferred to the IAEA database every 24 hours. At an predetermined interval all data are transferred to the distribution server located at the ARN laboratory at Ezeiza, Argentina. Remote access to data from the distribution server will be made from IAEA headquarters Vienna Austria, from ABACC in Rio de Janeiro Brazil, from the IAEA field office in Buenos Aires, from ARN, and from Sandia National Laboratories Albuquerque New Mexico.

INTRODUCTION
BACKGROUND: The primary objective of this system was to demonstrate that continuity of knowledge can be maintained throughout the transfer process from the spent fuel pond to the silo
field using radiation sensors to monitor the transfer path. The ultimate goal was to develop a system that could reduce inspector effort and operator burden while providing strong Safeguards assurance-or-verification of material. Following system development, under a DOE/Argentina bilateral agreement, changes and modifications to meet IAEA standards were identified, reviewed and agreed to by ARN, and implemented prior to installation at Embalse. A system formal test plan was generated and tests were conducted at SNL, LANL, and at the IAEA prior to the installation.

SYSTEM DEVELOPMENT

System development was started under a bilateral agreement between DoE and Argentina. At the conclusion of the development, the system was introduced to the IAEA for comments. Changes to the system were identified by the IAEA, reviewed and approved by ARN, and changes made to the original requirements. The system was modified to include as many of the changes that could be added prior to the first fuel transfer campaign and the others will be implemented prior to the second fuel transfer campaign. The Test Plan stipulated that the system would be tested for two fuel transfer campaigns before a decision would be made to upgrade it to Category A equipment. The original fuel transfer campaign schedule called for two campaigns in 1998, but during the first campaign the decision was made to have only one campaign in 1998. The second campaign to test the system will be in early 1999. Figure 1 is a diagram of the Embalse Remote Monitoring System.

![Diagram of the Embalse Remote Monitoring System](image)

Figure 1.

HARDWARE

The hardware consists of six gamma sensors and one neutron sensor. Each sensor communicates with one another and to the Datalogger via Echelon nodes on a Local Operating Network (LON). Five of the sensors communicate with the LON using RF transmission. The sixth sensor is
hardwired into the LON because it is mounted inside the Welding Hot Cell. The RF carrier is at 915MHz, which was approved by the Embalse facility. In addition to the radiation sensors, two devices were added to the system to provide status of the transfer process for the facility operator. The first of these devices is an LED counter-Red/Green Light indicator. This device counts the number of spent fuel bundles that have been loaded into the transfer flask (Flask #1), located in the spent fuel pond. The second device is a Red/ Green light indicator mounted in the Hot Cell room. Its primary function is to provide a status indication that radiation sensors D1, D2 and D3 are functioning properly so that the welding process can commence. The sensor designations are D1 through D6. Radiation sensor D1 (gross gamma) was designed and developed by the technical branch of ARN of Argentina. This sensor is mounted at the base of the grappling tool and the transmitter is mounted at the top of the tool. The receiver for D1 is located at the end of the spent fuel pond just above Junction box #1. The D1 receiver is connected to the network through the Echelon node. Sensors D2 and D4 (gross gamma) are commercially available sensors, obtained from Ludlum Measurements, Inc., and are connected to Sandia developed Straight-line transmitters. The transmitter provides the RF communication to a Straight-line receiver, which is connected to the Echelon node. The receivers for D2 and D4 are located inside the Hot Cell room. Straight-line receiver #1 monitors the communication for D2 when it is in the pool area and when it passes from the pool area into the Hot Cell room. This receiver also monitors sensor D4 when the basket is loaded into Flask #2. Straight-line receiver #2 monitors sensor D4 from the Hot Cell out to the silo area. Los Alamos National Laboratory provided sensor D3 (gross gamma and neutron). Sensor D3 is hardwired to a GRAND3, which is connected to an ILCON node that communicates with the Datalogger. Sensor D5 and D6 were provided by Oak Ridge National Laboratory. These sensors measure gross gamma radiation and were designed to be placed inside a 2-inch diameter silo inspection tube. The output of each sensor is connected to a Straight-line transmitter. Flat antenna ribbon cable was used to interconnect the antenna and the RF transmitter. Flat ribbon cable is required so that when Flask #2 is positioned on top of the silo, its weight does not crush the cable. The receiver for D5 and D6 is mounted on the outside wall of the Turbine Hall facing the Silo field. The transmission distance is approximately 300 meters. The storage device that gathers the data for the sensors is an IEC Datalogger. This device resides on the LON network and appears to the rest of the system as just another node. All sensors are bound to the Datalogger. The Datalogger is connected via RS-232 to the MOS-MUX server, which stores all the data for the sensors until it is transferred to the main server at Ezeiza.

SOFTWARE

The operating system platform is Microsoft NT 4.0. This OS allows multi-tasking and remote access capability. Data from each sensor is stored in files on the Datalogger. The Datalogger has the capability to store data for an extended period of time. These files are transferred, at the request of the data acquisition software, and populate the database located on a hard drive inside the MOS-MUX Server. Sandia National Labs developed the Data Acquisition Software. All other software used is commercially available.

SYSTEM INTEGRATION

System components were tested and evaluated by the organizations that developed them. The Echelon network was developed and tested at Sandia. All components were shipped to Sandia for final testing and system integration.
TESTING

Aquila Technologies Group (ATG) and Sandia developed a formal test plan, which provide the guidelines for testing the Embalse Remote Monitoring System (ERMS). The test plan was divided into phases identifying the requirements that needed to be met and the organization responsible for the test. The first part of the test was conducted at Sandia National Laboratories and covered all of the hardware and software requirements. Sensor testing was accomplished by utilizing signal simulators to provide an input to the system. The second part of the test was conducted at Los Alamos National Laboratory. This part of the test was conducted at LANL because of the access to various radiation sources that could be used to expose each sensor to a real radiation level. This testing was accomplished successfully in mid-February 1998. The final part of the testing was a burn-in test conducted at the IAEA in Vienna Austria. This test is an IAEA requirement and must be completed prior to the system being shipped to Argentina. This test was completed successfully.

INSTALLATION and FUEL TRANSFER MONITORING

Installation of the Embalse Remote Monitoring System was accomplished from April 19 through May 12, 1998. The installation occurred during the last few weeks of the spent fuel transfer campaign, which started in the first week of March, 1998. All members of the ERMS team from each Laboratory as well as ARN, ABACC, and IAEA personnel were instrumental in the installation. Pre-installation work, such as identifying the location of the junction boxes and the installation of most of the conduit, was accomplished by ARN personnel prior to our arrival. As each component of the system was successfully installed, testing of the component commenced. As the transfer process was being conducted, new information was being gathered to adjust the system for proper operation. Following the evaluation of the data that was gathered by the system, changes have been identified that will improve the performance of the system.

DATA EVALUATION

Data collected by the ERMS is very limited since the installation occurred towards the end of the fuel transfer campaign. The data that were collected were extremely valuable and showed that the radiation sensor trail can be followed from the spent fuel pond to the silo field. Each sensor performed as expected and the following graphs show the radiation profile for each.
The graph for D1 shows multiple bundles that were transferred into Flask #1.

This graph indicates Flask #1 leaving the spent fuel pool and being transferred into the welding hot cell where the lid was removed and the basket moved onto the welding table.

This graph shows the gross gamma peak when the basket was moved passed the gamma sensor inside the welding hot cell.
This graph shows the neutron signal as Flask #1 is moved into the welding hot cell, as the lid is removed from the flask, as the basket is moved from the flask to the welding table, as the welded basket is raised into Flask #2, lowered back into the welding hot cell and finally raised completely into Flask #2.

This graph shows the radiation signature of the basket being moved into the welding hot cell, raised into Flask #2, and the flask being transferred to the silo area.

This graph shows the basket being lowered into the silo.
This graph shows the basket of spent fuel being lowered into the silo.

**SYSTEM IMPROVEMENTS**

Following the installation of the ERMS at Embalse, some deficiencies in the system were identified that will need to be addressed prior to the second campaign. These are as follows:

- The addition of store and forward capability for each sensor must be incorporated to prevent the loss of data should RF transmission between the transmitter and receiver be disrupted.
- The authentication of sensor data must start at the sensor head. This may be accomplished using tamper indicating enclosure or unbroken conduit.
- The Echelon LON network is bandwidth limited which prevents high-speed data being transferred across the LON. This is only a problem in cases where high-speed data such as gamma spectroscopy must be transmitted.
- All sensors must pass a third party vulnerability review.
- Sensor D1 must be modified to include neutron counting along with the gross gamma measurements.

In summary, the system must be able to cover all credible diversion scenarios identified by IAEA and ABACC in the Embalse Working Group Task.

**CONCLUSION**

Evaluation of the data gathered during the spent fuel transfer campaign shows that continuity of knowledge can be maintained during the transfer of spent fuel from the spent fuel pond through the welding hot cell and the welding process, out to the silo field, and into the silo. Upgrades and enhancements scheduled to be incorporated into the system prior to the second fuel transfer campaign will increase the performance and capabilities of the system. Following the Evaluation performed by the IAEA during and after the transfer campaign, it is anticipated that the system will be upgraded to category A equipment.