SAND96-1937C
CONF-960767--15

PNC/DOE REMOTE MONITORING PROJECT AT JAPAN'S JOYO FACILITY

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ABSTRACT

The Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan and the United States Department of Energy (DOE) are cooperating on the development of a remote monitoring system for nuclear nonproliferation efforts. This cooperation is part of a broader safeguards agreement between PNC and DOE. A remote monitoring system is being installed in a spent fuel storage area at PNC's experimental reactor facility Joyo in Oarai. The system has been designed by Sandia National Laboratories (SNL) and is closely related to those used in other SNL remote monitoring projects. The Joyo project will particularly study the unique aspects of remote monitoring in contribution to nuclear nonproliferation. The project will also test and evaluate the fundamental design and implementation of the remote monitoring system in its application to regional and international safeguards efficiency. This paper will present a short history of the cooperation, the details of the monitoring system and a general schedule of activities.

INTRODUCTION

The first Safeguards Agreement between the Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan and the United States Department of Energy (DOE) was put into effect on 31 March 1988 for a duration of 5 years. This PNC/DOE Agreement was extended beyond its original termination date in 1993 and was then followed by a second Agreement that included the addition of "nonproliferation" in its title. The second PNC/DOE Agreement was put into effect on 15 September 1993 for an additional 5 years.

The present (second) Agreement is commonly referred to as the PNC/DOE Agreement for Cooperation in Safeguards and Nonproliferation and when combined with the first Agreement, it represents a mature relationship that has resulted in more than 20 separate projects to date. These projects include such topics as the development of waste measurement systems, upgraded glove box accounting systems, improved safeguards methods for nondestructive assay measurements of holdup and scrap materials, and safeguards systems for measuring vitrified high level waste canisters. Other topics include the installation of a fuel

This work was supported by the United
State Department of Energy under Contract
DE-AC04-94AL85000.

assembly monitoring system at PNC's Fugen reactor and studies of fundamental designs of a containment/surveillance system for the Advanced Thermal Reactor (ATR).

The inclusion of nonproliferation issues to the Agreement in 1993 has prompted both PNC and DOE to discuss various cooperation possibilities concerning nuclear nonproliferation. Both organizations have agreed to work jointly in the areas of remote monitoring and transparency. A general description of PNC's efforts in the area of nuclear nonproliferation can be found in another paper[1] in these proceedings. On 2 November 1995 an agreement was signed by PNC and DOE to explore the unique aspects of remote monitoring (RM) in the field of nuclear nonproliferation by installing, testing, and evaluating a RM system at PNC's experimental reactor facility Joyo in Japan.

The experimental fast reactor (FR) facility Joyo is located at PNC's Oarai Engineering Center (OEC) which is about 120 km northeast of Tokyo in Ibaraki Prefecture just south of the town of Oarai along the Pacific coast. Joyo is the first sodium-cooled FR to be constructed in Japan. It first achieved criticality in April 1977 and it is now capable of producing a rated power output 100 MWt. Joyo is the predecessor of PNC's prototype fast breeder reactor (FBR) facility Monju.

The remote monitoring system mentioned has been designed and developed[2] by Sandia National Laboratories (SNL) and most of the system's components are being provided by SNL. An unattended integrated portion of the RM system will be installed in Joyo's second spent fuel storage building which contains the facility's third spent fuel storage pond. This portion of the system will contain all the components necessary for on-site monitoring plus telecommunication hardware for the transmission of data to remote locations. Remote computer stations will be set-up at two PNC locations in Japan and one SNL location in the USA to access the on-site monitoring system and to download and review its collected and stored data. The system should be installed and functionally working by the end of July 1996.

This cooperative RM project at Joyo will be the basis of a study of how RM systems can be applied to nuclear nonproliferation issues. In addition to this study, the fundamental design of the RM system will be tested and evaluated through a field trial. The field trial will start immediately after installation for a duration of about six months. The field trial will provide valuable information on both technical and non-technical issues. The field trial will be very similar to trials performed by SNL and other institutions participating in SNL's International Remote Monitoring Project (IRMP). The expected benefits of remote monitoring include the reduction of operational and safeguards overall costs, thus a thorough evaluation of the RM system will be of benefit to other projects and applications.

TECHNICAL ASPECTS

The remote monitoring system consists of two parts: the on-site monitoring system and the remote-site access stations. The on-site system is actually a stand-alone system that consists of a network of sensors, a managing computer, a digital camera and a modem. The remote stations are data display, archiving, and processing computers with a modem connection. In this particular system conventional phone lines are used as the telecommunication link to transmit on-site collected data to remote locations. Please refer to Figure 1 for the system block diagram.

The system contains four different types of sensors: break beam, motion, gamma, and neutron. There are nine sensors altogether and each sensor is connected to a node. All the nodes are interconnected and form a Local Operating Network (LON). This LON is a commercially available modular system developed by Echelon Corporation. The LON has been designed so that all nodes can communicate with each other exchanging both sensor and state of health information. Each node is capable of processing data and providing authenticated data transfers over the LON. The connection of each of the nodes in the LON follows a Free Topology configuration. Four 18 gauge conductors are used to form the network cable that interconnects all the nodes. One twisted pair is used to supply

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DC power to all the nodes, while the other twisted pair carries the RS-485 communication signals. Each node and sensor combination is contained within a tamper-resistant enclosure, except for the gamma and neutron radiation detection elements.

A managing computer, or Data Acquisition System (DAS), is connected to a node and is part of the LON. The DAS is responsible for the collection of pertinent sensor information, the storage of data, data encryption, and telecommunication of data to remote sites. The computer can also issue instructions to the network nodes, such as changing the network configuration. The data are collected by the computer and stored on a hard disk or other storage medium. A modem is connected to the computer to provide telephone communication to remote computers. Encryption of the data is performed in the software rather than by modem.

be transmitted to the managing computer. The LON node microcontroller determines from the sensor information passed over to it on the network when to activate the ICAM to process an image.

The network nodes, sensors, and video camera are powered by a single power supply with battery backup. The computer is connected to main power via an uninterruptable power supply (UPS) made by American Power Conversion (APC UPS Model 600). The system can inherently indicate that a loss of power has occurred. All data transmitted to remote sites is encrypted within the computer software. Receiving stations must have the corresponding decryption software/key in order to make sense of the data. Initial access to the on-site computer begins with the necessary password. The data transmission rate is 9600 baud.

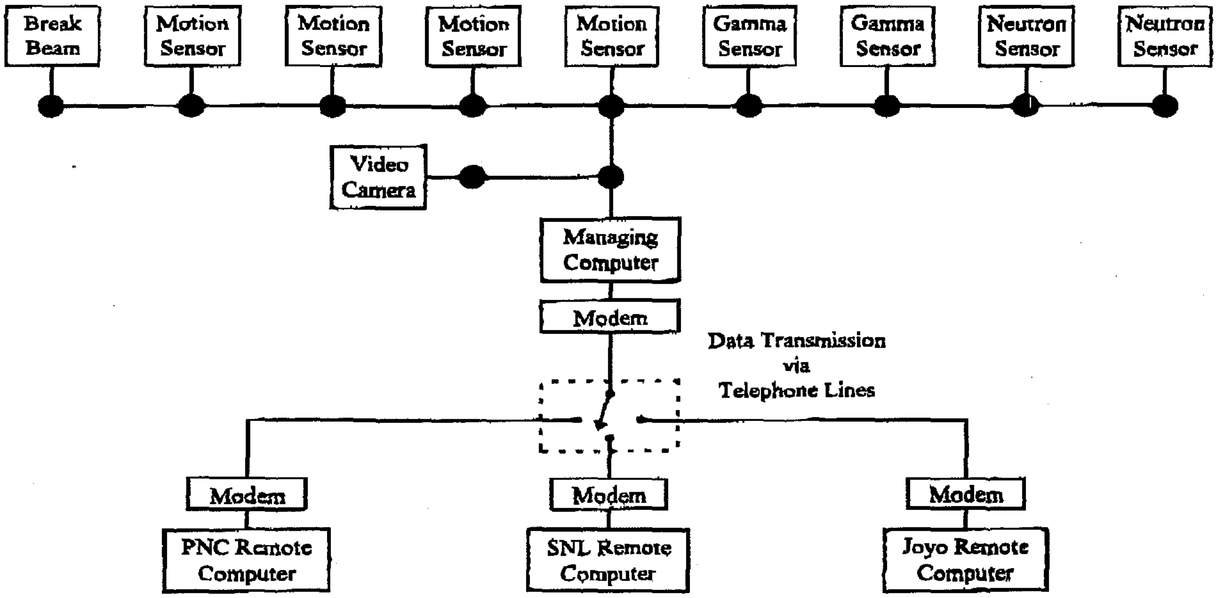

Figure 1. Joyo Remote Monitoring System Block Diagram

A video camera is also connected to a node through an Image Compression and Authentication Module (ICAM). The ICAM is capable of digitizing video frames, compressing the digital image, authenticating the compressed digital file, and storing the image file until it can

There are three remote sites that are able to call up the managing on-site computer, or DAS, to acquire information. One is located in another building at the Joyo facility, another is at PNC's headquarters in Tokyo and the third is at SNL's Cooperative Monitoring Center (CMC) in

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Albuquerque, New Mexico. Only one remote-site computer, or Data Image Review Station (DIRS), can be connected at any single time to the DAS. Information that can be accessed by a remote DIRS includes state of health readings on all nodes and sensors, records of previous events, trigger histories of video data, video images acquired, and the current status of the system.

The remote-site DIRS at PNC are Dell personal computers (OptiPlex XMT 5133 and GXM-5166 models) with Pentium processors running at 133 GHz and 166 GHz, respectively. They each have 32 Mbytes of memory, a 1.6 Gbyte hard disk, Microsoft DOS Version 6.2 and Windows 95 Operating Systems, and a Suntac modem capable of 28.8 Kbps.

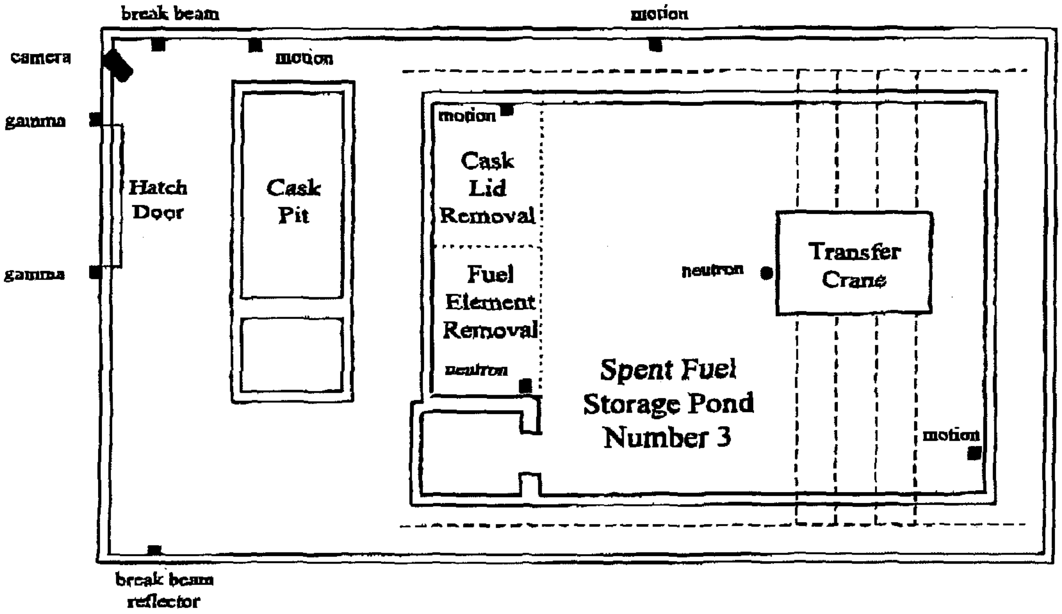

Figure 2. Joyo Spent Fuel Storage Facility #2

A sketch of Joyo's Storage Pond #3 showing sensor locations is shown in Figure 2. Spent fuel assemblies are transported in a cask and delivered to the outside of the storage facility's hatch door by truck. An overhead crane then transports the cask from the truck through the hatch to the Cask Lid Removal area in the storage pond. Two gamma sensors are located on the outside of the hatch opening, one on each side, at a height corresponding to the cask waist when passing through the hatch. The gamma sensors consist of Geiger-Mueller tubes that are sensitive to dose rates of about 1 mR/hr. The gamma sensors indicate the presence of nuclear material, and to some extent, the quantity of nuclear material present. Despite variations in the cask position or the unevenness of the radiation sources within the cask, the presence of a radiation source is indicated when the cask is passed through the hatch. The gamma sensors do not trigger a video snapshot of the hatch area, however a laser break beam and a motion detector on the opposite side of the hatch wall will instigate a video record.

The laser break beam sensor (Banner Engineering Corp. Q45BB6LL series) consists of two parts each located on opposite sides of the hatch opening in the pond room. One part is an active device which emits and detects the laser diode light information. The other part is a passive reflector. They are situated at the same height as that of the gamma sensors. Any cask or large object that passes through the hatch breaks the beam and registers that an item is present and

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passing through the hatch. A break beam interruption in excess of 3 seconds activates the camera and a digital image is recorded of the item passing through the hatch. If the beam remains interrupted, additional images are collected at predetermined time intervals.

The motion detectors are X-band microwave motion sensors (AM Sensors, Inc. MSM 10200 series) capable of providing non-contact sensing of moving metallic and nonmetallic objects within an adjustable detection area. A sensitivity/gain adjustment allows various object sizes, densities and distances to be selectively detected.

There are four motion detectors altogether. Two are located high on the pond room walls. One is located next to the active portion of the break beam sensor and detects movement in the hatch area as a compliment to the break beam sensor. The other sensor detects movement of the overhead crane (transports heavy objects inside facility) while it is in the pond room. The other two detectors are located near the edge of the pond and monitor movements at the pond surface. One monitors the surface of the pond where the cask lid and fuel elements are removed. The other monitors the pond surface towards the center of the pond and can also detect movements of the transfer crane (transports fuel assemblies inside pond) located just above the surface of the pond. Motion detected in the hatch area, at the surface of the pond, or in either of the two cranes will trigger the camera to record video images. As long as activity continues in these areas, images will continue to be recorded periodically. All motion sensors have been located and adjusted to minimize false triggering due to routine work in the pond room.

A neutron detector is used to distinguish between spent fuel and other objects being transferred into the storage pond as they are unloaded. Two neutron sensors are planned for implementation, although only one is needed. The additional neutron sensor is currently being developed by a Japanese supplier. It will be located on the gripper arm (holding fixture) of the transfer crane and will be in a position that corresponds to the mid-section of each fuel assembly. Information will be sent from the sensor via a fiber optic cable to its node above the pond's surface fixed on the transfer crane. From there a radio frequency (RF) transmitter will relay the information away from the transfer mechanism to an RF receiver located on the wall which connects directly into the LON. This neutron detector under development may be a preferred detector design, however it will not be available when the system is initially installed.

The nominal neutron sensor that is presently available is located in the pond adjacent to the Fuel Element Removal area. The neutron sensor's sensitive element consists of lead shielded ^{3}He tubes and is housed in a water-tight stainless steel tube about 34 cm long and 5 cm in diameter. A cable runs from a water tight connector up a rod that extends above the pond's surface. The cable connects the water-tight enclosure to a box containing the sensor electronics. The electronics box and the system network node are located in a tamper-resistant enclosure. The bottom end of the neutron sensor is at a depth that corresponds to the mid-point of the fuel element assemblies after they have been raised and removed from the cask.

The magnitude of the neutron signal as the assemblies are passed by the sensor are used as an attribute indicator of the elements. In order to accomplish the discrimination measurements, the neutron detector node operates continuously while the cask is being unloaded, accumulating counts for periods of a few tens of seconds. Motion detectors monitoring the pond's surface trigger the neutron detector to start counting. These counts are reported to the computer. The computer examines these sequences of counts per time interval in order to identify local maxima that correlate with activities in the facility. The time and magnitude of these maxima are recorded for subsequent analysis. Since the periodic video collection due to the motion sensors is adequate, the neutron detector does not trigger a video record.

The video camera is located high in a corner of the pond room where it can view both the pond area and the hatch entrance area. It has a 2.6 mm lens with a 180 degree view. The camera is capable of supplying continuous motion video data, but in this system it is used only to supply digital still images via the ICAM. The system is set to

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transmit the digital image over the LON to the managing computer. A separate dedicated video line can be used, if a higher video data transmission rate is desired.

FIELD TRIAL OBJECTIVES

The main objective of the field trial evaluation is the demonstration of the technical feasibility of the RM system. This includes the overall system reliability, data authentication on-site and across the link to the remote site, data confidentiality in the remote transmission, and the conclusiveness of the results based on the data. Technical parameters and protocols will be examined to define not only a better upgraded system, but a system that would be accepted as an international safeguards standard.

A technical examination will evaluate on-site software, the remote computer data display and management, telecommunication routes and means, sensor effectiveness and various component interfaces. Other examinations include the amount of data (especially digital images) that can be stored, the time necessary to connect from a remote computer and access data, the probability of successful telephone connections and complete data transmissions, the frequency of computer re-boots, maintenance requirements, and individual hardware reliability.

There will be several actual fuel movements and various staged scenarios that will be performed at the spent fuel storage site during the field trial period. The data collected during these times will be very valuable in testing the system. It will provide sufficient opportunities to adjust and test various parameters that will add to the quality and confidence of the final assessment of the system. The final report will help with the design of improved systems in the future by identifying both weak and strong features of the trial system.

SUMMARY

This cooperation between PNC and DOE will study the unique aspects of remote monitoring in the field of nuclear nonproliferation. A remote monitoring system is being installed in a nuclear spent fuel storage area at PNC's Joyo facility. The system has been designed and developed by Sandia National Laboratories (SNL) and most of the system's components are being provided by SNL. The on-site monitoring data will be stored on an on-site computer where the data can be easily accessed by computer stations at three different remote locations.

The system will be installed by the end of July 1996 and will be functionally tested within two weeks after installation. Then a field trial will begin and last about 6 months in order to test and evaluate the technical and non-technical aspects of the remote monitoring system. In parallel with this field trial there will be a study of how this type of remote monitoring system can be applied to other facilities in the fuel cycle. The study will include how a remote monitoring system can be used in order to enhance efficiencies in domestic and international inspection efforts and how it applies specifically to nuclear nonproliferation.

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State Department of Energy under Contract
DE-AC04-94AL85000.