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THE INTERNATIONAL REMOTE MONITORING PROJECT

RESULTS OF THE FIRST YEAR OF OPERATION AT EMBALSE NUCLEAR POWER STATION IN ARGENTINA.

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Abstract

As a part of the International Remote Monitoring Project, during March 1995, a Remote Monitoring System (RMS) was installed at the Embalse Nuclear Power Station in Embalse, Argentina. This system monitors the status of four typical Candu spent fuel dry storage silos. The monitoring equipment for each silo consists of: analog sensors for temperature and gamma radiation measurement; digital sensors for motion detection; and electronic fiber-optic seals. The monitoring system for each silo is connected to a wireless Authenticate Item Monitoring System (AIMS). This paper describes the operation of the RMS during the first year of the trial and presents the results of the signals reported by the system compared with the "on site" inspections conducted by the regulatory bodies, ABACC, IAEA, ENREN. As an additional security feature, each sensor periodically transmits authenticated State-of-Health (SOH) messages. This feature provides assurance that all sensors are operational and have not been tampered with. The details of the transmitted information and the incidents of loss of SOH, referred as Missing SOH Event, and the possible causes who produced the MSOHE are described. The RMS at the Embalse facility uses gamma radiation detectors in a strong radiation field of spent fuel dry storage silos. The detectors are Geiger Muller tubes and Silicon solid state diodes. The study of the thermal drift of electronics in GM detectors and the possible radiation damage in silicon detectors is shown. Since the initial installation, the system has been successfully interrogated from Buenos Aires and Albuquerque. The experience gained, and the small changes made in the hardware in order to improve the performance of the system is presented.

Introduction

The National Board of Nuclear Regulation of Argentina (ENREN) and the US Department of Energy (DOE) sponsored the installation of a RMS at the Embalse Nuclear Power Station, located in Cordoba, Argentina. The Embalse facility, which houses one power reactor and spent fuel dry storage silos, provides an excellent site to test the concept of front-end detection. This is because the major activity of safeguard's interest is the movement of spent fuel, which occurs during six months every year at this plant..
The RMS field test in Argentina have been operational for almost sixteen months. Motion and temperature sensors and the fiber optic seals have performed fairly well. GM radiation sensors experimented some drift due to temperature changes while silicon radiation detectors showed radiation damage during the first year of operation.

Technical description.

A full technical description of the RMS installed in Argentina has been published in reference (1). Some changes have been made to the original system which include the

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installation of an external modem, in order to improve the telephone data link. In addition, a new version of the control software was used.

Test results

A proper analysis of all the components of the RMS can be carried out by grouping them in the following way:
- Data transmission by telephone lines;
- Hardware;
- Radiofrequency link;
- Motion sensors;
- Fiber optic seals;
- Temperature sensors;
- Radiation sensors.

Data transmission by telephone lines

After analyzing several alternatives, a commutted telephone line was chosen, due to the easiness and the rapidness of its installation in the site. This line is an analog one, since only a fraction of the Argentinean telephone network is digitalyzed. By the other hand, the final link between the telephone company and the nuclear power plant is done through a microwave system with a reduced bandwidth which deeply deteriorates the signal to noise ratio. Previous tests performed between the Ezeiza Atomic Center (CAE) and the Sandia National Laboratories (SNL) showed that the maximum transmission speed for a stable data link was 4800 baud. Afterwards, the communication trials carried out between SNL and the Embalse NPS demonstrated that the limit speed between both facilities was 1200 baud. Higher speeds produced loss of carrier effect which interrupted the communication. Having into account the above expressed results, it was decided to operate at 1200 baud.

Hardware

Concerning the hardware of the Receiver Processing Unit (RPU), it behaved properly, since only the floppy disk drive of the computer had to be replaced. This demonstrates the adequacy of an industrial computer for this application. By the other hand, it was found that most of the failures occurred while establishing the communications were produced by the internal modem, which hanged up the system. This was caused by the fact that several peripherals shared hardware interruptions and, sometimes, it provoked hardware malfunctions. This problem was dealt with by using a RS232 serial interface, which allowed full interruption and I/O address selection. The RS232 serial interface was defined as Com-3 and it was connected to an external modem. By this way, the communications were improved and their evolution could be verified through the front pannel LED's.

Radiofrequency link

Each pair detector-transmitter periodically emits a signal indicating its proper performance; this signal, received by the computer, not only indicates that the radiofrequency link is operative but also authenticates the message. During the first year of operation, this behaviour was studied and the causes of some failures were detected.

Fig. 1 shows the RPU report on the missing SOH occurred in an approximately 100 days period.

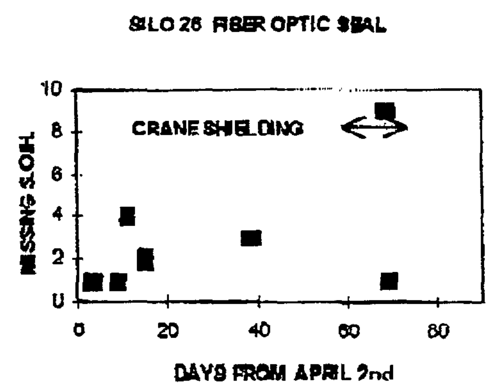

Fig. 1

A thorough analysis of the data clearly demonstrated that, in a major proportion, maintenance and inspection jobs on the silos or the operation of the bridge-crane over them, interfered the RF link. In those cases where a clear explanation could not be found, adverse meteorological conditions or signal collisions between transmitters were assumed to be responsible of the above mentioned failures. Anyway, each sensor emits about 8600 SOH signals per month, being approximately 5 those reported by the RPU as missing ones, indicating the high reliability of the system.

Motion sensors

Motion sensors were placed at the silo instrumentation tubes, in order to verify the positioning of both the radiation detector and the lid of the silo, which conducts to the inner baskets. The data report of the motion sensors is shown in Fig. 2.

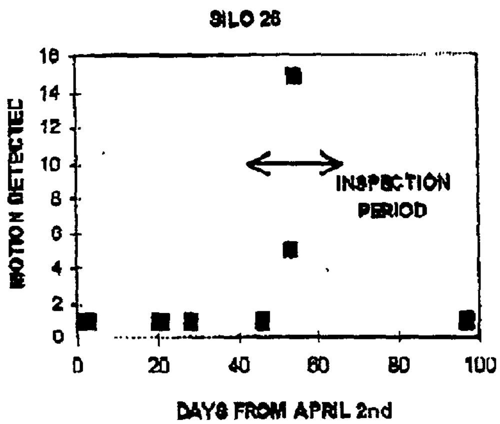

Fig 2.

Background signals prevails during a period of about 50 days, and a marked increase of motion detection signals appears after this period covering one or two days. This fact correlates fairly well with an inspection period. In cases, when a less important rate of signals above the background were detected, a coincidence with different jobs performed on the silos sector such as spent fuel transfers involving bridge crane operation was found. Background signals may be attributed to the high sensitivity of the detector, which allows the detection of quite weak movements such as those produced by rainfalls or the occurrence of birds on the silos. This spurious contribution may be eliminated by reducing the detector's sensitivity.

Radiation sensors

The radiation sensors are based on Geiger-Müller detectors and solid state semiconductor detectors (Silicon diodes).

The dose rate indicated by the GM detectors and its associated electronic chains (HV power supply, preamplifier and amplifier) showed slight fluctuations around a main value since the installation of the system. It was demonstrated that this effect was temperature dependent; and, having into account that the temperature at the detector's location stayed almost constant during the periods under consideration, it was assumed that the daily changes on the temperature only affected the electronic chains. As shown in Fig.3, the major value of the dose rate is registered at noon.

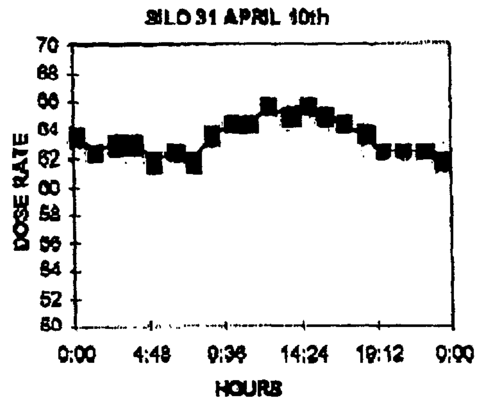

Fig 3

Fig. 4 shows the temperature variation during the same period (one day) corresponding to the electronic chain location.

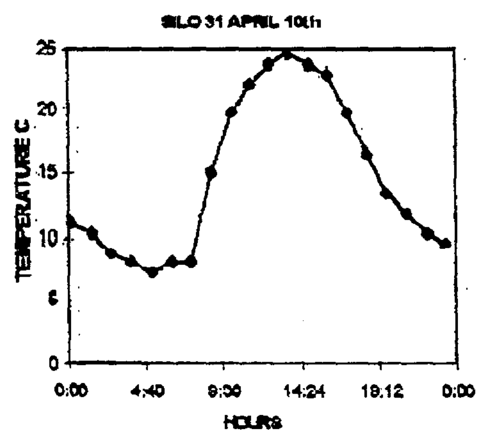

Fig. 4

The correlation between the dose rate and the temperature can be visualized in Fig. 5. The lineality of this correlation allows the application of a temperature correction factor to the dose rate measurement between 5 and 40 oC.

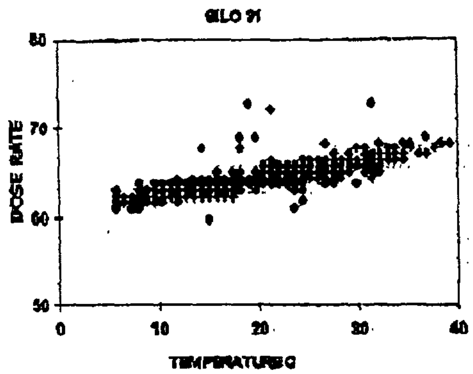

Fig. 5

The dose rate measurements performed during twelve months, corrected for temperature, are represented in Fig.6. The values show a decreasing behaviour, fairly coincident with the radioactive decay of a typical CANDU burnt fuel element.

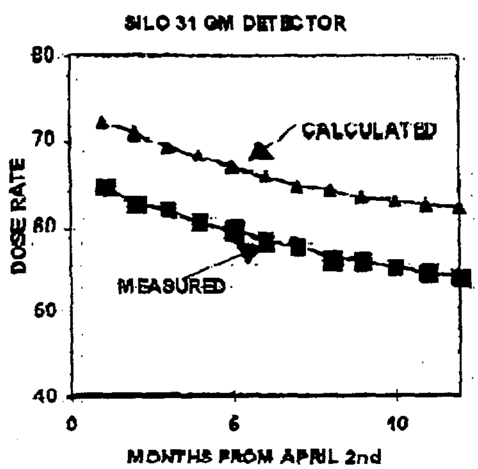

Fig. 6

Regarding the semiconductor detectors, since the tungsten shielding had to be taken out from the onset due to mechanical aspects, the dose rate measurements did not represent the right values. This situation was corrected by applying a lineal factor, while it was demonstrated that the whole system, detectors plus electronic chains, were not affected by the daily temperature variations (Fig.7).

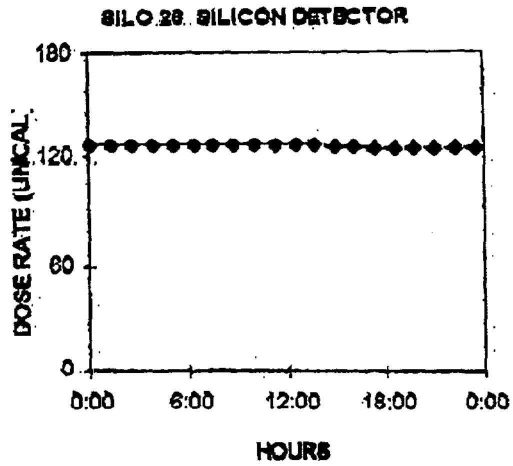

Fig. 7

On a long term period, a decreasing tendency of the measured values can be seen. This tendency does not correlate to the radioactive decay process, and it can be explained by a

decrease of the counting efficiency of the detector, caused by radiation damage (Fig. 8). In order to support this assumption, it should be taken into account that the semiconductor detectors receive a monthly dose of 360 Gy, which is high enough to produce severe radiation damage on this kind of detectors.

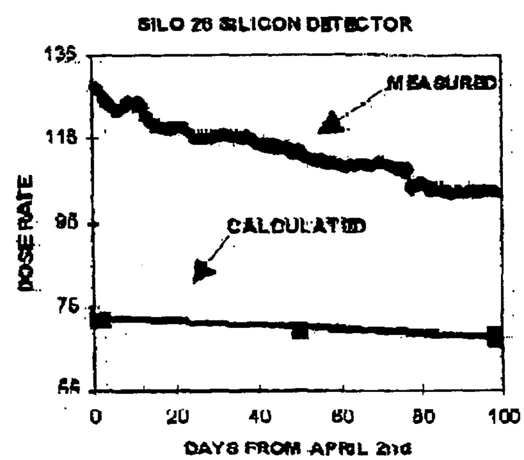

Fig. 8

In order to solve this problem, the above mentioned detectors were replaced by ionization chambers on May, 1996.

Fiber optic seals.

The performance of these devices was fully acceptable, without any indication of fiber optic rupture. Only a few cases of missing of SOH were reported, most of them due to interferences or shielding of transmitters or collisions among signals from similar remote control devices. By the other hand, the lithium batteries were replaced by another ones with a higher capacity, since the performance of the former was not satisfactory.

Temperature sensors

These devices, connected to both radiation and motion detectors, have shown a proper behaviour during the first year of operation.

Conclusions

The experience gained during the first year of operation of the system demonstrated its adequacy for safeguards purposes.
The "on line" remote operation and the possibility of its settlement without interfering with the normal plant activities, make this system an attractive alternative to routine "in situ" safeguards inspections.
The use of authentication and a trustful RF transmission technique assures that the information has not been tampered on purpose, allowing the use of this system in many high security installations.

Acknowledgements

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