Investigation Study on Gamma Ray Imaging Technology for Nuclear Power Plant Decommissioning

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1. Introduction

The gamma ray imaging system used in US nuclear power plants for decommission has a CCD coded aperture camera utilized to produce color overlays identifying the highest gamma source in the field of view. The gamma ray imaging system provides an estimated dose-rate of the source at 30 cm above. The gamma detector is a terbium activated glass scintillator. The system is capable of producing a color two-dimensional image of a radiation field superimposed on a black and white visual image. The system used in US power plants consists of a portable sensor head that contains both gamma ray and visual imaging systems and a portable control computer. The gamma ray imaging system has been successfully used as an ALARA tool for identifying source terms and determining the adequacy of existing shielding. Because the control system can be positioned away from the camera, the radiation exposure to personnel can be reduced without extensive shielding requirements. The gamma ray imaging system has been used to date in the decommissioning of Maine Yankee, Big Rock Point, Trojan, San Onofre1, and Millstone 1. The equipment has also been used at normal refueling outages at a number of commercial nuclear power plants and at several Department of Energy Decommissioning sites.

This paper is intended to review the applicability of gamma ray imaging system as decommissioning tool. In order to review the actual applicability, we are going to introduce applications for US power plants.

2. Gamma Ray Imaging System

The gamma ray imaging system provides a two-dimensional color image of a gamma radiation field superimposed on a black-and-white visual image. The gamma image has a spectrum of colors to provide a qualitative measurement of gamma intensity. Red and orange colors represent the higher intensities, yellow and green intermediate intensities, and blue and purple lower gamma intensities. The gamma ray imaging system consists of a portable sensor head that contains both gamma ray and visual imaging systems controlled by a portable computer.

Visual and gamma ray data are collected and displayed on the computer, which can be located up to two hundred feet from the portable sensor. The images are usually displayed on the computer''s liquid crystal display (LCD) screen. The gamma ray imaging system sensor head is normally mounted on a tripod.

The visual image is capture by a standard video camera. Both the collection time and the field-of-view are controlled by computer input. The radiation and visual images are stored on a disk in a PC format for future use.

3. Investigation of Field Application

Investigation of field application for commercial decontamination and decommissioning has included Maine Yankee, Trojan, San Onofre-1, Big Rock Point, and Millstone-1. In each instance the gamma ray imaging system was used to provide supplemental radiation source term information. Extensive manual surveys had been performed at each of the five sites. The gamma ray imaging system was used to search for new source terms or to obtain additional information on previously identified source terms. The greatest success occurred at Maine Yankee where twelve new source terms were identified and approximately 200 person-rem were saved. Summaries of the decommissioning field experience at each if the sites are provided below.

Maine Yankee is an 864 MWe PWR owned by Maine Yankee Atomic Power Co. and several other utilities. The unit began operation in 1972 and was shut down in August 1997 for economic considerations. Maine Yankee selected Stone & Webster as the decommissioning operations contractor.

In January 1999 Maine Yankee personnel performed a comprehensive survey of the reactor and auxiliary buildings using the gamma ray imaging system. The unit had been shut down for approximately eighteen months and had been manually surveyed.

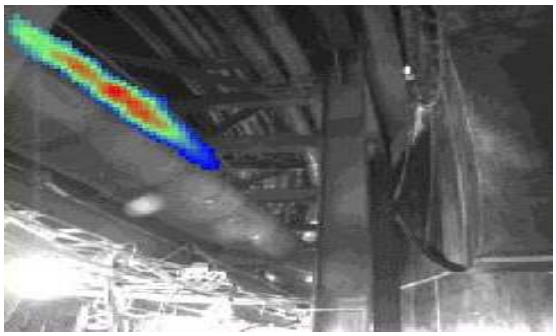

Fig. 1. Overhead source from a small pipe(Maine Yankee)

The gamma ray imaging system survey revealed twelve new radiation sources and helped characterize approximately 300 previously identified sources. The new sources were primarily in overhead areas, which were difficult to reach and survey by conventional methods. Figure 1 shows an overhead source from a small pipe.

Trojan is a 1130 MWe nuclear plant owned by Portland General Electric (PGE). The unit began operation in 1975 and was shut down in November 1992 because of economic and operational considerations. The unit had been shut down over six years before the gamma ray imaging system was brought on site in March and April of 1999.

The plant had been extensively surveyed and the radiation levels had significantly decreased since the plant shutdown. A unique feature of the Trojan decommissioning was the shipment of the reactor vessel, with all its internals, to a lowlevel waste disposal site in Washington State. Trojan personnel used the gamma ray imaging system to take pictures of the reactor vessel for shielding planning purposes and then performed a post shielding evaluation prior to shipment for burial. A post-shielding image of the reactor vessel is shown in Figure 2. This image shows that additional shielding is needed in the nozzle area.

Trojan personnel were pleased with the gamma ray imaging system results but plant procedures still required that manual radiation surveys be taken prior to any radioactive material being shipped off-site. In order for the gamma ray imaging system results to be accepted as an official record, the equipment must be calibrated against known sources and plant procedures must be appropriately modified.

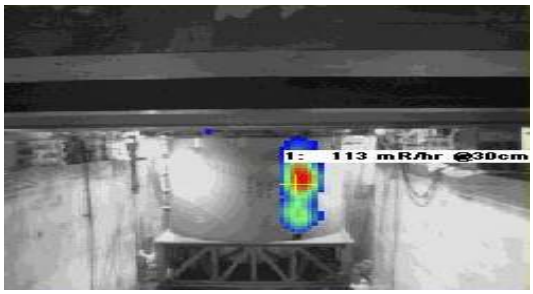

Fig. 2. A post-shielding image of the reactor vessel(Trojan)

San Onofre-1 is a 436 MWe PWR owned by Southern California Edison Co. The unit began operation in 1968 and was shut down in November 1992 because of economic considerations due to safety related retrofit requirements. San Onofre-1 personnel performed a general characterization of the reactor and auxiliary buildings in May 1999. The San Onofre-1 site had been shut down six-years prior to the gamma ray imaging system being on site. The areas had been extensively surveyed and the characterization was quite complete. Still, new information was obtained in several areas.

Figure 3 shows a shielded cavity drain line. The gamma ray imaging system image shows precisely where additional shielding would be beneficial. Figure 4 shows a gamma ray imaging system image of the San Onofre-1 surge tank. Again, the image shows the extent and source strength of the contaminated area.

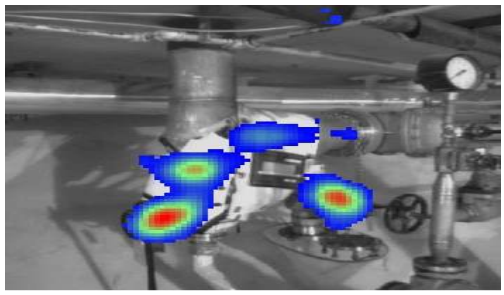

Fig. 3. A gamma ray image of shielded cavity drain line(San Onofre-1)

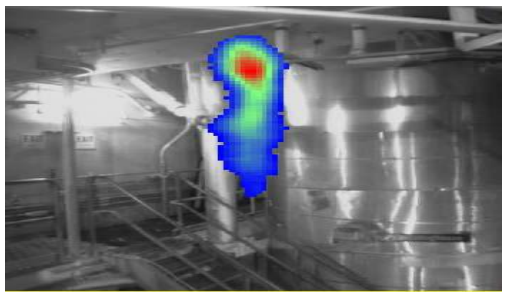

Fig. 4. A gamma ray image of surge tank (San Onofre-1)

Big Rock Point is 67 MWe BWR owned by Consumers Energy. Big Rock Point began commercial operation in 1965 and was shut down in August 1997. Since the shutdown work has begun to restore the 600-acre site to a green field. A primary system chemical decontamination was performed using EPRI's DfD process in early 1998.

The gamma ray imaging system was used at Big Rock Point to perform a general characterization survey. The unit had been shut down for approximately two years and had been manually surveyed. Although the equipment worked satisfactorily, Big Rock Point personnel indicated that additional training would have been beneficial.

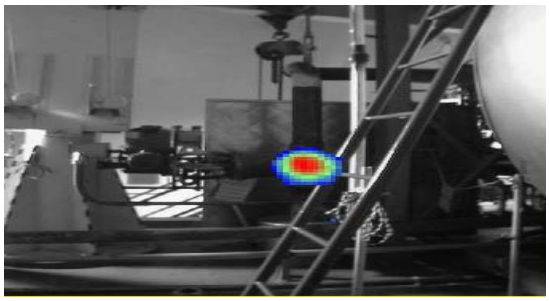

Fig. 5. A gamma ray image of surge tank (San Onofre-1)

4. Conclusion

The gamma ray imaging system used in US power plants consists of a portable sensor head that contains both gamma ray and visual imaging systems and a portable control computer. The system has been successfully used as an ALARA tool for identifying source terms and determining the adequacy of existing shielding. Because the control system can be positioned away from the camera, the radiation exposure to personnel can be reduced without extensive shielding requirements. And also, the gamma ray images can be easily stored and retrieved for record keeping or for any future use. The gamma ray images are most beneficial when the equipment is used within a reasonably short time after shutdown.

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