Application of Remote Gamma Imaging Surveys at the Turkey Point PWR Reactor Facility

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ABSTRACT
The RadScan™ 800 4π Gamma Imaging System was used at the Turkey Point PWR Nuclear Plant over a two-day period on February 1st and 2nd, 2006. The unique RadScan™ 800 is a remote operated gamma spectroscopy scanning system that is capable of quickly and safely locating and identifying radiation hazards. Using proven technology the RadScan™ 800 remotely locates and characterizes gamma radiation anomalies with exceptional accuracy in a wide variety of environments, including building surfaces, hot cells, in or on glove boxes and process vessels, and within excavations. Three surveys were conducted using the RadScan™ 800 on the Unit 4 fuel transfer canal at Turkey Point. For the first survey, the RadScan™ 800 was set up on the east end of the fuel transfer canal. In this orientation the west wall and a portion of the bottom of the canal were surveyed. For the second survey, the RadScan™ 800 was positioned directly over the canal more to the west side. In this orientation the east wall of the transfer canal was surveyed. For the final survey, the RadScan™ 800 was mounted horizontally to the spent fuel bridge and placed directly over the transfer canal. In this orientation the entire bottom of the canal was surveyed. Dose rate survey maps were produced and compared against gamma and video imaging. Exact locations of hot particles were pin pointed within the fuel transfer canal providing vital information to assist in ALARA practice and planning.

INTRODUCTION
The RadScan™ 4pi gamma imaging system is a remotely operated, highly collimated, scanning Low Resolution Gamma Spectroscopy (LRGS) detector combined with video capture and data handling and analysis software [1,2]. An assembled RadScan™ system is shown in Fig. 1. The detection system is comprised of a detection head located onto a pan/tilt unit. An electronics control box is attached to the pan/tilt unit and provides initial processing of the radiation detection signal as well as positioning electronics. The RadScan™ can be assembled by a single individual on the standard tripod (shown in Fig. 1) or mounted to a vehicle using the quick release coupling flange. The detection assembly is powered from the workstation via an umbilical cable that can be up to 80 m in length. The workstation is powered by 110V.

Figure 1 RadScan™ 800

The detection head, shown schematically in Fig. 2, houses a Na(I) scintillation detector encased in a Tungsten collimator with a 4-degree aperture. While the default aperture is 4-degrees, this can be reduced to increase the spatial resolution of the measurement using either a 3-degree or 2-degree insert. Located next to and in-line with the collimator are a laser range finder and a conventional CCD camera with automatic zoom and aperture. The system has been designed to be used within harsh environments such as outdoors and within airborne contaminated enclosures.

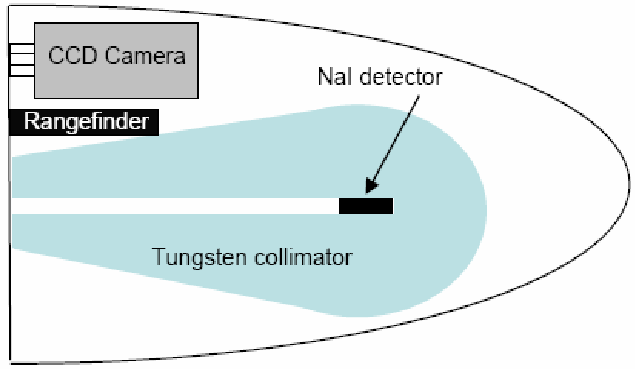

Figure 2: Schematic cross section of the RadScan detection head

To construct a radiometric overlay image the RadScan™ must acquire both radiometric and conventional image data for the entire area to be surveyed. This data is acquired in a series of 'single shot' acquisitions. Once initiated, the acquisition process is fully automated requiring no manual intervention or monitoring.

Once an Automatic Scan is initiated the pan/tilt unit moves the detector head to the start position at the top left hand corner of the area to be surveyed. The head will stay at this position for a user defined time known as the Dwell Time. During the Dwell Time the radiation detector will count and record the energy of those gamma rays that are incident on the detector through the highly collimated field-of-view (FoV). A low resolution gamma energy spectrum, a photographic image and a detector-source distance is recorded at each dwell position. The diameter of the FoV will depend upon the collimator aperture selected and upon the distance to the object being measured [at a distance of 10m and using the 4-degree collimator the FoV will be a circle of approximately 70cm diameter]. The pan/tilt unit then moves the detector head to the next position where the measurement process is repeated ensuring an overlapping FoV. The process continues until a raster-scan (grid scan) of the entire area to be surveyed has been performed. Since RadScan™ is a truly directional radiation detector, the only gamma rays that will have been detected (other than those scattered into the FoV) will have originated from gamma emitters within each FoV of the detector.

When the acquisition is complete the radiometric color overlays can be viewed immediately requiring no further processing of the data. Alternatively, the data can be extracted off the system and viewed on any PC using the RadScan™ Analysis Software. The count rates from each dwell position are overlaid as color contours onto the conventional photographic images thus creating a radiometric overlay image. A powerful feature of the RadScan™ is the ability to select an energy-region-of-interest (ROI) for the data analysis either pre or post acquisition. This provides a number of advantages.

First, a radiometric image showing a particular isotope of interest can be displayed. For example, when looking at historic fuel waste, the 661.7 keV gamma emissions arising from Cs-137 will dominate the gamma spectrum. Selecting an ROI ranging from 645keV to 675keV will display only those count rates that form the 661.7 keV photopeak and hence the measurement results are focused on Cs-137. Secondly, the region of interests used on the system can be changed during offline analysis to look at other radionuclides as necessary. Thirdly, the effects of scattered gamma radiation may be almost eliminated from the display. The ability to do this largely depends upon the isotopes detected and the gamma spectrum acquired. To increase overall sensitivity it is common to set an ROI containing the full range of gamma energies from 30 keV to 1500 keV.

SYSTEM SAFETY

In September 2002, team members from the Operating Engineers National HAZMAT Program (OENHP) conducted an occupational safety and health assessment of the RadScan™: 700 Gamma Imaging System via a review of documentation for the equipment at the Department of Energy (DOE) West Valley Demonstration Project (WVDP) in West Valley, NY. A What-If analysis, a standard tool for hazard analysis, was used to generate a Human Factors Assessment Report (OENHP #2002-33 Version A)[3] and a corresponding Technology Safety Data Sheet (TSDS DOE OST TMS # 1793)[4]. Though the human factors assessment and TSDS were conducted on a previous model of the RadScan™, they are still generally applicable to the new system model, with the main changes being redesign of the system to be lighter and more compact improving ergonomic concerns. Copies of the Human Factors Assessment Report and corresponding TSDS developed by the Operating Engineers National Hazmat Program can be found on the internet at http://www.iuoeiettc.org/Pdf%20files/HFA/RadScan.pdf.

CALIBRATION AND DATA QUALITY ASSURANCE

An energy calibration check of the instrument was performed with a ^{137}Cs source. The spectra produced from this source was analyzed using Ortec Maestro® spectral analysis software and the centroid of the 661.7 keV peak from ^{137}Cs was noted 654 keV with a FWHM of 20 keV.

ISOTOPIC CHARACTERIZATION

Although the RadScan™ has been used for numerous applications, the system has the capability to differentiate between many gamma-ray signatures within the range of 30 to 1500 keV. At the Turkey Point site the default ROIs were set for the isotopes listed in Table 1.

Table 1. Potential Isotopes of Radiological Concern

Nuclide	Half-Life	Energies (keV) and Intensity of Major Radiations		
		Alpha	Beta (AVG)	Gamma
^{60}Co	5.271 y		95.77 (99.88%)	347.14 (0.0075%)
			625.8 (0.12%)	826.10 (0.0076%)
				1173.22 (99.85%)
				1332.49 (99.98%)
				2158.57 (0.0012%)
^{137}Cs	30.17 y		174.3 (94.4%)	661.66 (85.1%)
			416.3 (5.6%)	

SURVEY PARAMETERS

The basic approach to data analysis was to identify hot spots and/or anomalies where gamma radiation is being emitted that may contribute to a higher than expected general area dose rate. The spectra of each scanned area was evaluated over the full spectrum range as well as specifically for the key gamma-ray listed in Table 1 for the regions listed in Table 2. In addition, a dose rate contour analysis using Microsft™ Excel integral to the RadScan™ Analysis software was performed for most scans for comparison purposes. The rapid dose rate measurements are normalized to 30 cm, that is dose is reported as mrem/hr at 30 cm. The dose is always scaled by distance using the laser range finder and can be adjusted in the range of (0.1-100 meters). The dose rate maps should be considered indicative only and the default range can be adjusted prior to conducting a scan to 0.1 meters or 10 cm to be more representative of surface dose on contact (see the bolded notes below for more explanation).

Note: The Rapid Dose feature on the RadScan™ system provides an indicative estimate of the gamma dose rate. The feature is calibrated for point sources located at the center of the field of view (FOV), at a user specified distance from that FOV. Under calibration conditions the dose estimates should be in agreement with reading that a health physics dose rate meter would produce, but for distributed sources or for sources not located at the center of the FOV then the two may not agree.

Table 2. Measurement Parameters

Scan	**Collimation**	**Dwell Time (s)**	**Full Spectrum Energy Range (keV)**	**Co60 ROI (keV)**	**Cs137 ROI (keV)**
Survey 1	2^o	5	30 - 1500	1100 - 1500	550 - 810
Survey 2	2^o	5			
Survey 3	2^o	5			

SURVEY 1 WEST WALL OF TRANSFER CANAL

The first survey was conducted from the east end of the transfer canal with the RadScan™ positioned upright. The survey was conducted of the entire west wall but the only area of concern was toward the bottom as shown in figures 3 and 4.

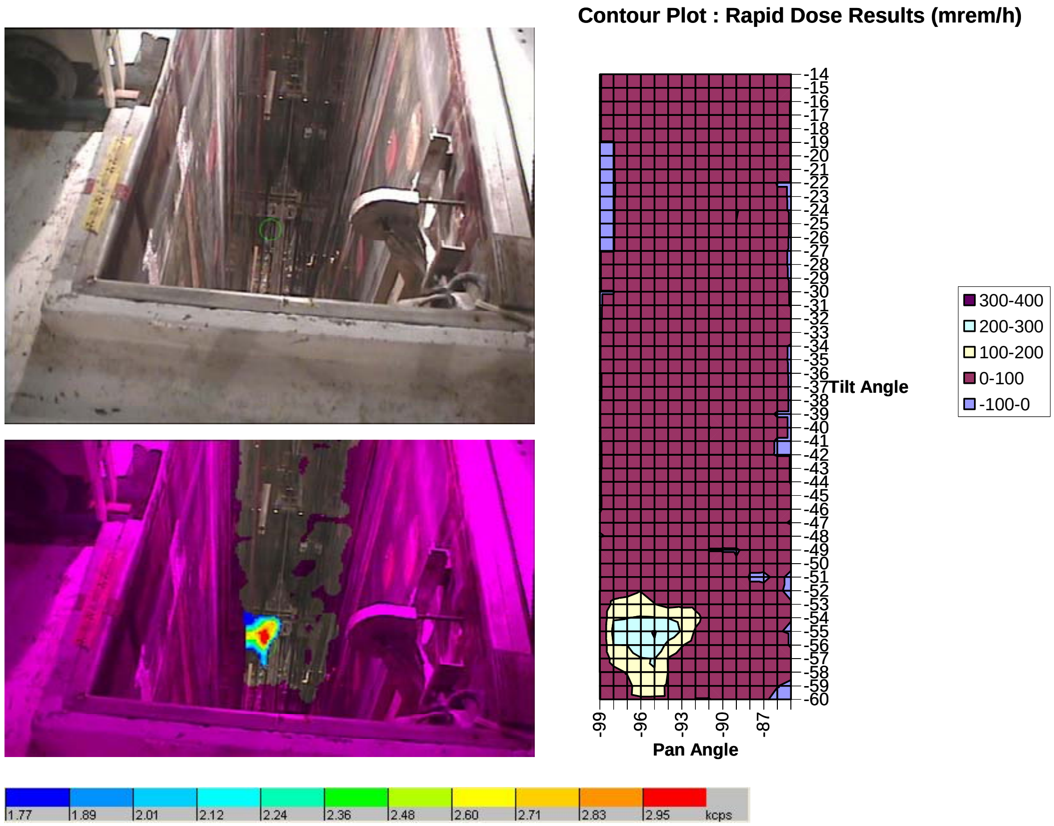

Figure 3. Survey 1 Gamma Image Overlay Compared Against Dose Rate Map

Figure 4. Full Size View of the Location of the Most Elevated Dose and Count Rate Found In Survey 1

SURVEY 2 EAST WALL OF TRANSFER CANAL

Figure 5 presents the results of the survey of the east wall of the transfer canal. The RadScan™ was positioned on two steel plates directly above the canal towards the west wall. Due to the downward angle limitation of -60^{o} a full survey of the east wall was not possible. It was then decidied to mount the RadScan™ horizontally on to the bridge and survey the entire bottom of the canal in this manner (Survey 3).

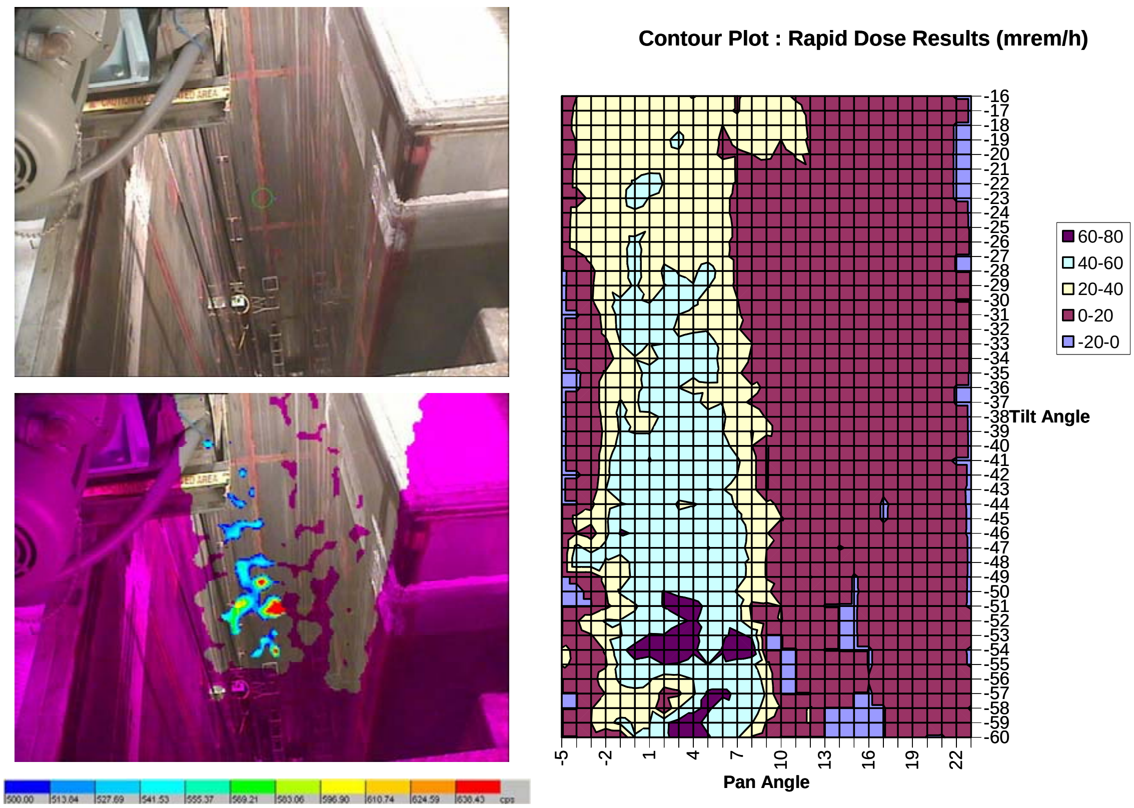

Figure 5. Survey 2 Gamma Image Overlay Compared Against Dose Rate Map

SURVEY 3 BOTTOM OF TRANSFER CANAL

The RadScan™ was mounted horizontally onto the bridge and positioned directly over the transfer canal. Figure 6 present the gamma image overlay results compared against the dose rate map.

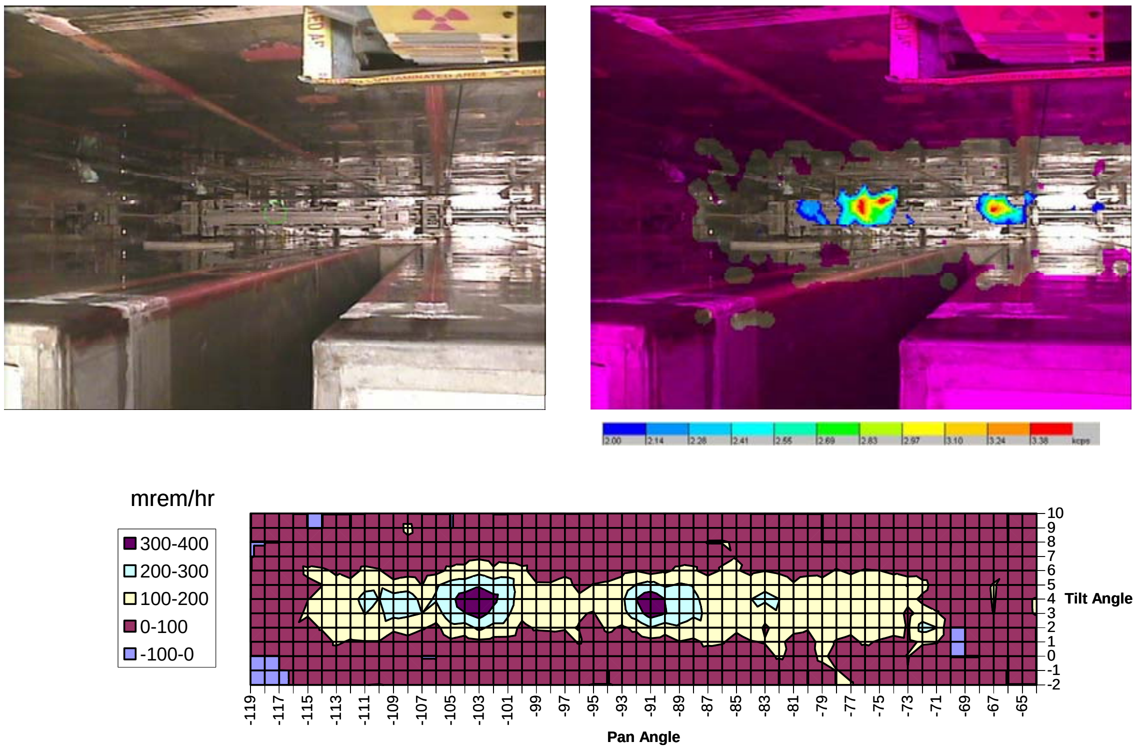

Figure 6. Survey 3 Gamma Image Overlay Compared Against Dose Rate Map

CONCLUSION AND RECOMMENDATIONS

BIL Solutions, Inc. performed a two-day campaign in February 2006 at Turkey Point using its RadScan®: 800 gamma imager to survey the plant's fuel transfer canal which produced dose rate survey maps from several perspectives that were then compared against gamma and video imaging.

The combination of video and gamma images was an effective ALARA tool that allowed the team to pin point sources in the canal, develop a strategy to maximize the effectiveness of the decontamination, and determine the packaging and shielding methods necessary to disassemble and remove fuel transfer equipment without ever putting a worker in the canal. Conducting repairs in the fuel transfer canal is a challenge faced by many of the U.S. commercial nuclear power plants, but now with the successful use of RadScan at Turkey Point, a viable and safe option for reducing worker exposure has been successfully deployed.

The RadScan™ 800 has been demonstrated at a number of other power plants in numerous different applications including Pickering A CANDU, Prairie Island PWR, Watts Barr PWR, and Peach Bottom PWR. Special thanks to Dave Sluszka and Brian Carberry at Turkey Point, Jeff Leclaire at Prairie Island, Ken Grimm at Watts Barr, the ALARA personnel at Peach Bottom, and the esteemed Dr. Maung Zeya at Ontario Power Generation.

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[2] REMOTE TWO DIMENSIONAL GAMMA IMAGING OF WIDE AREA HIGH DOSE ENVIRONMENTS USING THE RADSCAN® : 800 4PI GAMMA IMAGER
S. Hepworth / P. Griffiths/ DJ Thornley/ PA Clark,BIL Solutions Ltd
ICEM'05: The 10th International Conference on Environmental Remediation and Radioactive Waste Management September 4-8, 2005, Scottish Exhibition & Conference Centre, Glasgow, Scotland ICEM05-1112

[3] Human Factors Assessment Report (OENHP #2002-33 Version A)

[4] Technology Safety Data Sheet (TSDS DOE OST TMS # 1793)