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RadBall Technology Testing for Hot Cell Characterization

Eduardo B Farfán*, Trevor Q. Foley*, G. Timothy Jannik*, John B. Gladden*, Donald Mackenzie**, Steven J. Stanley+,
Chris J. Holmes+, Mark Oldham++, John Adamovics+++, John R. Gordon*, and Larry J. Harpring*

**Savannah River National Laboratory, SRS, Aiken, SC 29803 eduardo.farfan@srnl.doe.gov*
***US Department of Energy, Headquarters, Germantown, MD 20874 donald.mackenzie@em.doe.gov*
+ National Nuclear Laboratory, Risley, Warrington, United Kingdom steven.j.stanley@nnl.co.uk
++ Duke University Medical Center, Durham, NC 27710 mark.oldham@duke.edu
+++ Heuris Pharma LLC, Lawrenceville, NJ 08648 jadamovics@mail.cosi.org

INTRODUCTION

Operations at various U.S. Department of Energy sites have resulted in substantial radiological contamination of tools, equipment, and facilities. It is essential to use remote technologies for characterization and decommissioning to keep worker exposures as low as reasonably achievable in these highly contaminated environments. A significant initial step in planning and implementing D&D of contaminated facilities involves the development of an accurate assessment of the radiological, chemical, and structural conditions inside of the facilities. Collected information describing facility conditions using remote technologies could reduce the conservatism associated with planning initial worker entry (and associated cost).

DESCRIPTION OF THE ACTUAL WORK

A new, non-electrical, remote radiation mapping device known as RadBall has been developed by the National Nuclear Laboratory (NNL) in the United Kingdom. The baseball sized device offers a means to collect 3-D information regarding the severity and distribution of radiation in a given hot cell, glovebox, or room. [1, 2]

The device consists of two constituent parts shown in Fig. 1A: an inner core and an outer collimation shell. The inner core is made from a radiation sensitive polymer material. On manufacture, the inner core is transparent; however, on exposure to radiation the material exhibits an increase in opacity. The outer collimation shell is cast from tungsten, and contains numerous individual collimation holes.

Once the device is deployed in a radioactive area, the collimation shell partially attenuates the incident radiation while preferentially allowing radiation to pass through the collimation holes. This radiation then deposits opacity tracks within the inner core which provides information required to locate, quantify and characterize the radiation sources. The orientation of the opacity track provides the positional information regarding the source (achieved by using a reverse ray tracing technique). The activity of the detected source is assessed by quantifying the magnitude of the opacity change (which follows a linear relationship with respect to absorbed dose). Radiation sources can be characterized by studying the depth of the opacity track (the measured opacity in the track over the depth of the track will follow a function that can be interpreted to estimate the characteristic energy or energies of the incident radiation source).

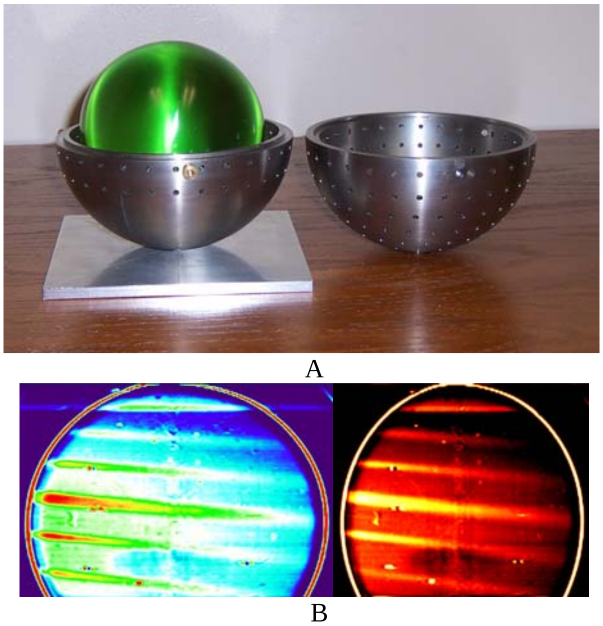

Fig. 1. A. Two components of a RadBall device: the outer collimation shell and inner polymer core (Image: SRNL). B. Optical scan images of a RadBall irradiated with a 5 Gy ^{137}Cs source (Images: NNL).

The RadBall technology was tested at the Savannah River Site Health Physics Instrument Calibration Laboratory (HPICL) in three phases involving 45 exposure scenarios to determine the optimal dose, collimator thickness and collimator hole size.[2] In addition, the RadBall technology was tested in a hot cell involving four exposure scenarios at Savannah River National Laboratory (SRNL).[2] After irradiation, the RadBalls were sent to Duke University for optical scanning. Data from Duke University (Fig. 1B) has demonstrated that the technology has responded well during these phases.[3]

RESULTS/LESSONS LEARNED

The experiments have highlighted that the optimal dose is around 1.5 to 3.0 Gy and that a collimator thickness of between 5 and 10 mm is preferred with collimator hole sizes of around 3 mm diameter. The experimental deployments have shown that the RadBall is effective in locating radiation doses from multiple angles and initial results indicate that for a distance of 1m, the technology is able to locate the radiation source within 1 cm. The experiments have confirmed the linear response of the polymer opacity when exposed to increasing levels of radiation. Data analysis to confirm the ability of the RadBall technology to accurately characterize different radiation sources is ongoing. Work has also been initiated in the development and building of the 3D visualization part of the technology to overlay RadBall data onto images of the radiation field environment.

In addition, RadBall was deployed in SRNL Hot Cell 9 in Building 773-A (Fig. 2). It was covered with plastic bags and removed successfully without becoming contaminated. Since the RadBall was visible though shielded glass, orientation was maintained by visually taking measurements with manipulator arms.

A B

Fig. 2. Hot Cell Deployment Environment (A: Hot cells at SRNL. B: Hot Cell 9 used for deployment) (Images: SRNL).

Since RadBall is a passive 3-D radiation detection device and contains no electronics, it cannot determine its location or orientation within a contaminated room. SRNL has developed a proof of concept device that will determine the RadBall's location and orientation within a room. For the proof of concept, the working parameters are a nine meter cube room with no obstructions, and flat floors. The location device must run on batteries long enough to determine the location and orientation and then save the data to nonvolatile memory. Major components of the system include an embedded computer, stepper motor, ultrasonic sensor, digital compass, power supply and battery (Fig. 3).

Future milestones involve the development of a robot for remote RadBall deployment into highly contaminated facilities, field-deployable optical scanner development, and RadBall deployment at another DOE facility using the robot and scanner to promptly obtain visualizations of the contaminated hot cell or glove box.

Application of the RadBall technology will allow characterization of highly contaminated areas and avoid the risk to personnel from hazardous levels of radiation. The small passive device does not require power and can be exposed in small confined rooms (3 m x 3 m). Multiple RadBalls can be used for larger areas.

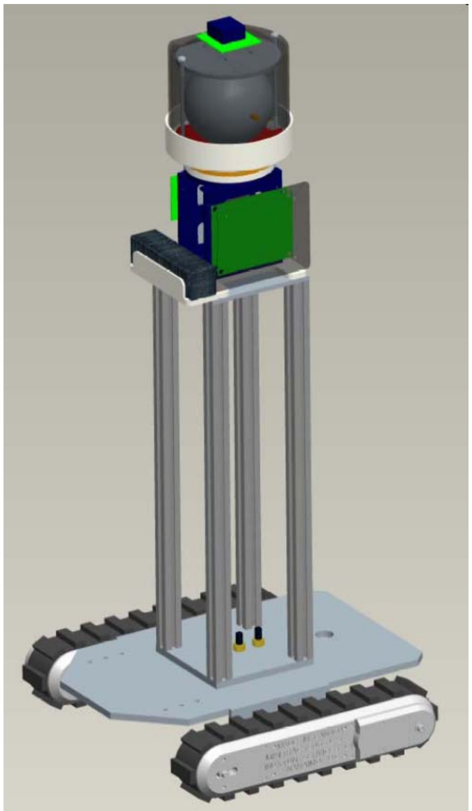

Fig. 3. RadBall Position and Orientation Device System on a robot (Images: SRNL)

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