Radiological investigations in hard-to-access zones by remote OSL/FO dosimetry

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Radiological inspections in hard-to-access zones (pipes, tanks, reactors, storage ponds, etc.) are achieved by OSL/FO dosimetry, coupled to geolocalization means in order to reconstruct the dose distribution inside the infrastructure, sparing heavy duty and large cost in the purpose of setting-up an optimized dismantling strategy.

KEYWORDS: Optically Stimulated Luminescence (OSL), Fiber Optics, Dosimetry

Introduction

The application of the immediate decommissioning strategy, advocated by the French Nuclear Safety Authority (ASN) with the aim to minimize exposition of workers, requires the use of innovative dismantling techniques (remote handling and robotics, remote dosimetry) that progresses gradually thanks to experience feedback. Among these, remote dosimetry is an essential dismantling tool as it enables to predict the impact of decontamination procedures in terms of worker exposition and to set up a cost-effective dismantling scenario associated with a risk analysis and waste management strategy.

In easy-to-access zones, gamma cameras are mostly used for radiological inspection on account on their performance. However, the decontamination process may prove complex, time-consuming and costly, especially for hard-to-access zones, *e.g.* inside tanks, reactors, storage ponds etc.

A particular critical case concerns the inspection through small-diameter pipes (< 1 cm) showing small radius of curvature (some centimeters) [1].

Commercial dosimeters used for this purpose are mainly Geiger-Mueller-GM or CdZnTe-CZT tiny detectors, connected to measurement units (placed away from radiological perimeter) with triax cables providing adequate electromagnetic (EM) shielding.

With the aim of providing long-range remote dosimetry (20 to 30 meters range or further) in hard-to-access zones, the deployment of these conventional dosimeters proves difficult on account on signal degradation due to cable length and limitations to miniaturization imposed by the presence of power supply and signal conditioning electronics (sometimes associated with thermal regulation electronics). Moreover, GM devices often require a modeling to retrieve dose rate from counting data.

An alternative solution was investigated by the CEA LIST during the past 20 years that is based on OSL/FO (Optically Stimulated Luminescence – Fiber Optics). OSL probes are located at the extremity of armored optical cables and are thus robust enough to be pushed and removed within pipes. Radiological profiles are reconstructed step-by-step (curvilinear coordinates).

The main advantages of the OSL/FO technique are EM and Cerenkov immunity, long-range remote operation, high miniaturization, high radiation resistance and wide range in dose rate detection (6 decades). Since OSL/FO is a passive dosimetry, it does not require local electronics to operate. As a consequence, the sensor head may be made very small (typically Ø =5 mm). The sensor is also waterproof and easy to decontaminate.

Based on a topographic modeling of the inner infrastructure under investigation, a dose reconstruction within every critical parts is usually achieved with the help of Monte-Carlo softwares (*e.g.* Mercure software designed by CEA DM2S/SERMA), sparing heavy duty that would otherwise be necessary to provide access to conventional dosimetric means.

Principle of operation of OSL/FO dosimetry

OSL detectors make use of OSL luminescent materials (Al_2O_3:C) affixed on the extremity of optical fibers [2-4] (fig. 1). This material stores charges generated by irradiation. Under laser stimulation, it is reset to zero and trapped electrons recombine onto recombination centers, leading to the emission of an OSL light which amount is proportional to the dose accumulated between two successive laser stimulations. The accurate measurement of both dose (from 1 mGy up to 1 Gy) and integration time (from 10 minutes up to weeks) provides an exceptionally wide range in dose rate, typically from 10 µGy/h up to 10 Gy/h (6 decades, *i.e.* 6 orders of magnitude). The measurement unit of the CEA LIST enables 16-channel detection by optical switching. OSL/FO dosimeters developed by the CEA LIST were field-tested on three dismantling sites in Marcoule and Cadarache, France.

Practical cases

Atelier Pilote de Marcoule (CEA-APM, Marcoule, France, 1998-2000)
Two OSL/FO devices were sold in 1998 by the CEA LIST to the CEA-DEN in order to provide radiological inspections of pipes within the APM. OSL fiber sensors monitored the amount of remaining activity, after successive washes involving solvents, dyes and acids. The added-value for CEA was to estimate the efficiency of the washing process and to optimize it from the economical point-of-view.

UP1 fuel factory (AREVA, Marcoule, France, 1999-2000)
The UP1 factory was stopped in 1996 after having run during 40 years in CEA Marcoule. A third OSL device has been sold to AREVA (formerly COGEMA) and tested on UP1 (MAR200), similarly to APM.

Réacteur Nouvelle Génération (CEA-RNG, Cadarache, France, 2016)
The RNG is a prototype reactor developed by CEA-DAM and AREVA-TA with the aim to qualify on-board reactor concept and technology for french submarines. It has been stopped in 2005. Radiological investigations were commissioned to CEA-DEN LMN by CEA-DAM in order to estimate inner remaining activities inside tanks. The LMN used the OSL/FO device from the CEA LIST to monitor dose rates along the access pipe and inner tank through a **doigt de gant** (Ø = 8.2 mm) [1]. The OSL data were used to reconstruct the dose inside the reactor volume (Mercure).

Figure 1: Left - view of the OSL/FO sensor and view of GM and CZT devices for comparison Right - insertion into pipes (CEA-DEN)

Figure 2 : View of OSL/FO multichannel device (CEA LIST)

Conclusion

The OSL/FO device and sensors developed by the CEA LIST are gaining acceptance in the field of decommissioning. Radiological data gathered in hard-to-access zones (pipes, tanks, reactors, storage ponds, etc.), coupled to geolocalization means, are used to reconstruct the dose distribution inside infrastructures, sparing heavy duty and large cost in the purpose of setting-up an optimized dismantling strategy. Current work if dedicated on the design of multi-channel fiber sensors in order to provide 1D activity profiles. The OSL/FO measurement unit is also re-designed in collaboration with SDS.

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