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Abstract: Brazil has experienced an expressive market of radioactive lightning rods in the 70's and 80's. These apparatuses are constituted by an air terminal to which one or more Americium-241 sources are fixed aiming at ionizing the surrounding air and enhancing the attraction of the atmospheric discharges. In 1989, the Brazilian National Nuclear Energy Commission (CNEN) lifted the authorization for manufacture and installation of radioactive lightning arresters, because their inefficacy was technically demonstrated. It also determined that replaced radioactive lightning rods were sent immediately to one of the centralized radioactive waste storage facilities for treatment as radioactive waste. Although the sources can easily be removed, some contamination is found all over the remaining metal scrap, requiring decontamination to allow its release as non-radioactive waste. Decontamination using various chemicals proved to be inefficient and generates large amounts of secondary wastes. Laser ablation is being evaluated as an alternative for decontamination. A Nd:YAG nanosecond laser is used with energy 300 mJ and results showed successful decontamination, leaving only a tiny amount of secondary waste to be treated.

Sao Paulo, September 26, 2012.

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Dr. Ademar José Potiens Júnior

LASER DECONTAMINATION OF THE RADIOACTIVE LIGHTNING RODS

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Highlights

- The process generates minimal additional secondary waste.
- The effectiveness of this technique may allow certain materials to be recycled reducing radioactive waste volumes.
- The process allows reuse of decontaminated metals.

1. INTRODUCTION

In the late 60's, when cheap radioactive sources were widely available, the 'radioactive lightning rods' (RLR) first conceived by Szillard in 1914, became feasible and were manufactured by the thousands in many countries. The proponents of these apparatuses claimed that the ionization of the air around the rods reduced the resistivity of air, creating an early stream of ascending discharge that improved the attraction power of, or widened the protected area by, the lightning rods (Veiko et al, 2011). Only around 1980 the radioactive early streamers were definitively dismissed by experts (Baigalmaa et al, 2009), although serious doubts about the effect of ionizing radiation on the incidence of lightning strokes had been raised earlier (Gillespie, 1965). When the license for manufacture and installation of the RLR in Brazil was suspended in 1989 (CNEN, 1989), about 75,000 devices were in place over the roofs of factories, commercial buildings, high storied residential buildings, schools, and other structures.

Each RLR was manufactured with one to ten sources, depending on the expected protection area required by the customer. The medium activity of these sources is around 7 MBq (Minematsu, 2009).

The radioactive source used in the RLR was a strip of americium oxide covered with a layer of a gold alloy that encapsulated the radioactive material and avoided its dispersion. The americium sources were mounted over a sheet of stainless steel which was in turn riveted to the plates of the terminal. Two of such sources are visible in the upper surface of the bottom plate of the RLR shown in the left picture of Fig. 1. Rivets visible in the top plate are evidence of other sources attached to the RLR shown.

The encapsulating layer of the sources had to be thin enough to allow alpha particles to be emitted without absorption and had to be made of noble metal to resist corrosion in the outdoor environment. Whether by negligent manufacture and installation or by wind erosion, however, the surface of the sources is usually dotted with microscopic punctures and scratches (Marumo, 2006) through which a bit of the source material escapes and contaminates the rods and the surrounding structures. Every piece of radioactive lightning rod received for treatment as radioactive waste showed at least a detectable level of surface contamination and a significant fraction of them presented contamination well above the limits for release of contaminated materials to the public domain. Although the contamination levels found pose no immediate risk to public health, the release of the radioactively contaminated metal is regulated and the material must be previously decontaminated or otherwise treated as radioactive waste.

The decision to hold back or to release rests on the costs for decontamination versus the costs for treatment as radioactive waste. The second alternative is somewhat expensive considering that the estimated number of lightning rods to be treated is of the order of 75,000 pieces. Therefore, either the development of a decontamination method or the adoption of an existing technology that are inexpensive and that achieve the required decontamination factor, is a key point in the management of this radioactive waste. There is a bonus in the decontamination option, which is the recycling of one or two kilograms of copper alloy per decontaminated piece, for more than fifty percent of all RLR. Most other pieces are made of stainless steel and a few percent were fabricated with tin plated carbon steel.

Some decontamination studies using a variety of chemical baths were carried out previously and the results were satisfactory (Dellamano, 2009; Fonseca, 2010), but these processes generated a relatively large amount of secondary liquid radioactive waste.

The aim of the present study was to evaluate the possibility of using of laser ablation to decontaminate the surface of the radioactive lighting rod parts after radioactive sources were removed.

2. EXPERIMENTAL SETUP

The laser used in this work was a nanosecond Nd:YAG (Quantell Brilliant), operating in the fundamental mode, 1064 nm, with a pulse duration of 5 ns and the energy per pulse was 300 mJ. No optical element was used to focus the laser beam in order to keep a long

confocal parameter thus avoiding that sample reliefs interfered in the spot size, which was 3 mm in diameter. This laser was selected as described in the literature (Veiko et al, 2011).
Due to the almost disk-like symmetry of the plates the laser beam was maneuvered with two dielectric plane mirrors (Layertec High Power designed for 1064 nm) mounted in kinematic supports that allowed the beam to scan entirely the surface of each face of the sample as shown in the Fig. 2. One of the mirrors was connected to a lever driven by a computer-controlled step motor and the plate was placed inside an especially built acrylic sealed box and made to rotate around its axe by another step motor.
The laser beam emerging from the laser head (left side of Fig. 2), was maneuvered with the mirror scanning system and injected through a glass window into the sealed box, where the sample was processed. Pressure inside the box was maintained below atmospheric pressure with a general purpose laboratory vacuum pump and a high efficiency particulate air filter thus avoiding any escape of contamination.
The 59 keV gamma emission of Am-241 from the RLR plates were measured before and after laser ablation with a Hyperpure Germanium detector (HPGe) from Canberra, model GX2518, and electronic setup composed of high voltage source, amplifier and multiport multichannel analyzer. The counting geometry was detector and plates coaxially mounted at 10 cm.

3. RESULTS AND DISCUSSIONS

One RLR plate is shown in Figure 3 before and after the laser cleaning process almost completely stripped of the painting. The scanning of each surface lasted 25 minutes.
Table 1 shows counting results for both sides of eight plates before and after laser ablation and the decontamination factors calculated as the percent of contamination removed.
The higher initial contamination levels were always on the side of the plates where the americium sources were formerly riveted, which were the upper side of all plates.
Where the area around the holes left by removing the rivets was most damaged low decontamination efficiencies were obtained. Some remnants of painting in plate crevices, fissures and cracks retained the americium particles what resulted in the lower decontamination factors observed for some plates. Smooth surfaces scanned always resulted in very high decontamination factors. This problem will be tackled by adjusting focus and other operational parameters as to optimize the process and achieve the required decontamination factors.

4. CONCLUSION

Laser cleaning was found to be a powerful method for radioactive surface decontamination. The results showed that this process is effective and generates the least possible volume of secondary waste. Moreover, it allows the reuse or recycling of the decontaminated metals, thus reducing radioactive waste volumes and management costs.

REFERENCES

Baigalmaa, B., H.J. Won, et al., 2009. A comprehensive study on the laser decontamination of surfaces contaminated with Cs+ ion. Applied Radiation and Isotopes. 67(7–8): 1526-1529.
CNEN, Comissão Nacional de Energia Nuclear, *Resolução nº. 4 de 19 de abril de 1989*, Diário Oficial da União, 09.05.1989, pp. 7.070 (1989).
Dellamano, J. C.; Silva, F. N.; Ferreira, R. J., *Decontamination of scrap arising from radioactive lightning rod treatment.* Associação Brasileira de Energia Nuclear. *Proceedingof 2009 International Nuclear Atlantic Conference - INAC 2009*. Rio de Janeiro, September 27 toOctober 2, 2009.
Fonseca, H. C. O.;Dellamano, J. C., *Descontaminação de sucata proveniente do descarte do desmonte de pára-raios radioativos.* Associação Brasileira de Energia Nuclear. *Proceedingof 2011 International Nuclear AtlanticConference - INAC 2011*. Belo Horizonte, October 24-28, 2011.
Gillespie, P.J., 1965. Ionizing Radiation: a Potential Lightning Hazard Nature. 208(5010): 577-578.

Marumo, J.T., 2006. Avaliação da contaminação provocada por pará-raios radioativos de Amerício-241 descartados em lixões. Tese de Doutorado, Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo, São Paulo.

Minematsu, D.; Dellamano, J. C.; Ferreira, R. J. *Activity determination of the Am-241 sources from radioactive lightning rods.* Associação Brasileira de Energia Nuclear. *Proceeding of 2009 International Nuclear Atlantic Conference - INAC 2009*.Rio de Janeiro, September 27 to October 2, 2009.

Veiko*, V.P., Mutin,T.Y., Smirnov, V.N., Shakhno, E.A., 2011. Laser Decontamination of Radioactive Nuclides Polluted Surfaces. Laser Physics. Vol. 21, No. 3, 608–613.

Table 1

Table 1 - Decontamination factors obtained with laser cleaning.

Plate	Surface	Before cleaning (cpm)	After cleaning (cpm)	DF* (%)
1	Upper	33771	3875	89
	Lower	8962	1662	81
6	Upper	13773	286	98
	Lower	10754	199	98
4	Upper	18218	902	95
	Lower	1858	162	91
2	Upper	8909	4723	47
	Lower	3207	2358	26
5	Upper	4036	566	86
	Lower	1077	212	80
8	Upper	123	3	97
	Lower	65	2	96
7	Upper	812	129	84
	Lower	209	28	87
3	Upper	10501	4006	62
	Lower	4144	1805	56

(*) DF = Decontamination Factor

Figure Caption

LIST OF FIGURES

Figure 1

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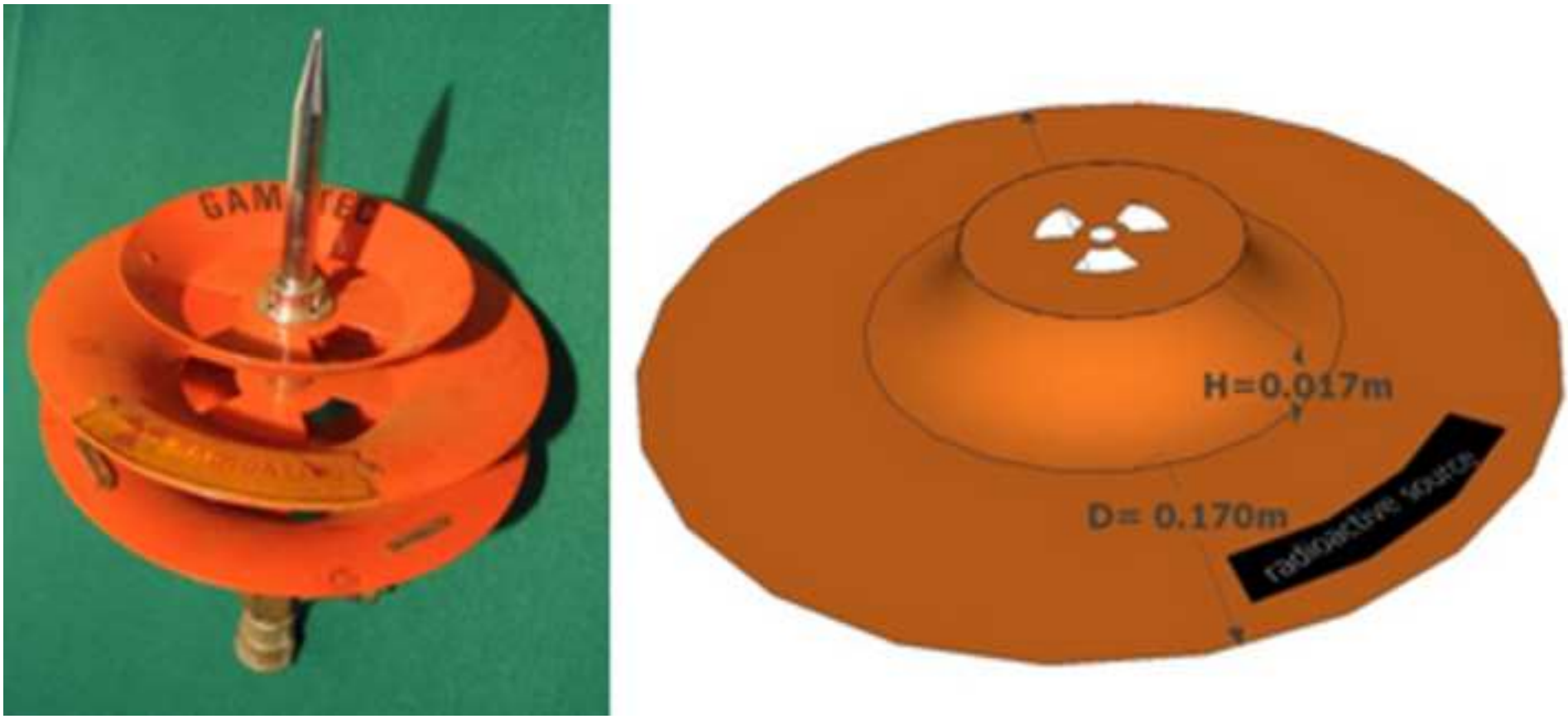

Figure 2

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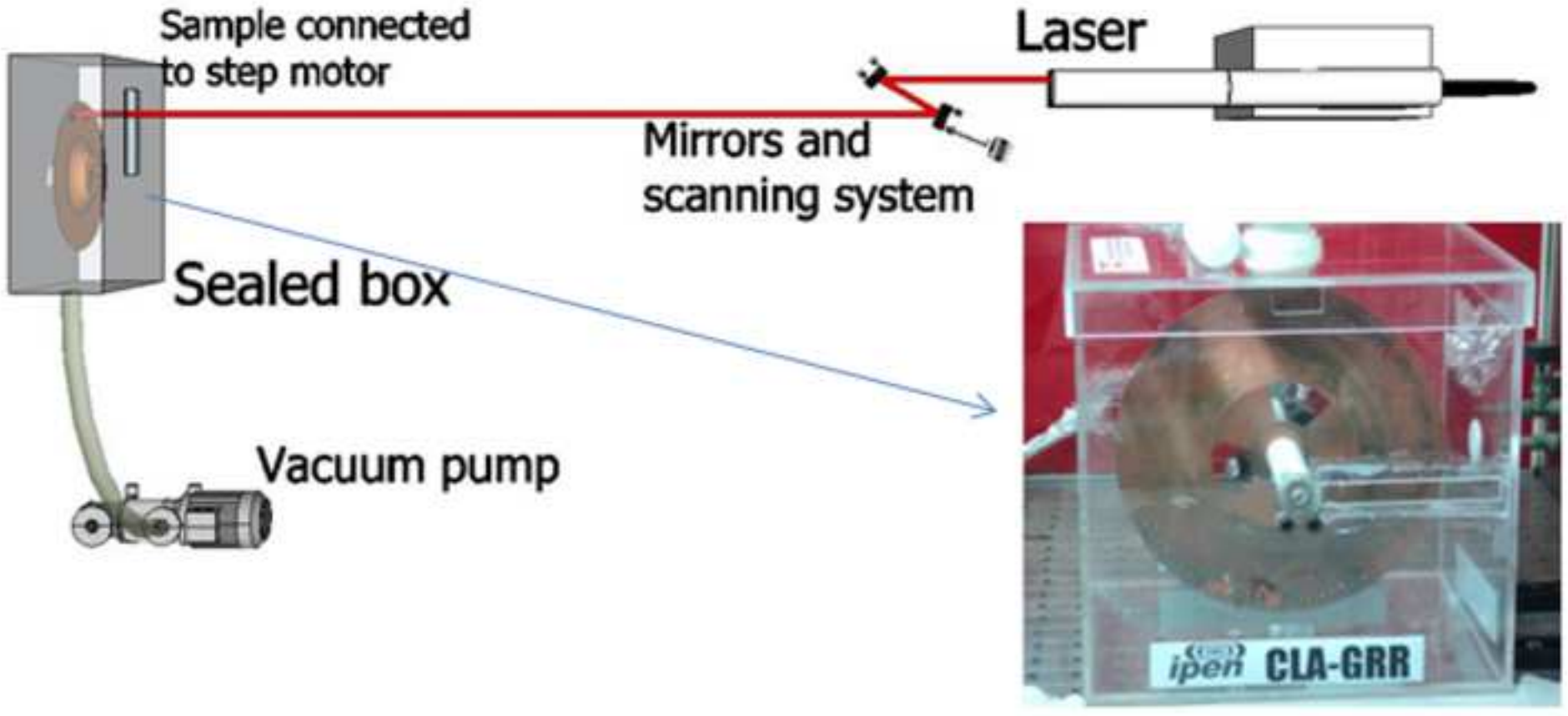

Figure 3

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