RADIATION SHIELDING DESIGN ASSESSMENT OF NUCLEONIC GAUGES

J. D. R. L. Gomes[1], R. S. Gomes[1], M. L. L. Costa[1], Z. D. Thomé[2], G. H. F. Caldas[1]

[1] Brazilian Nuclear Energy Commission, Rio de Janeiro, Brazil
[2] Military Institute of Engineering, Rio de Janeiro, Brazil

INTRODUCTION

Nuclear gauge is a control and measuring device activated by the radiation emitted by one or more sealed radioactive sources. It includes a source holding and a detector. In recent years, several standards have been issued by different international committees in order to specify requirements for the design of nucleonic gauges taking into account issues related to radiological protection. The aspects of design and manufacturing of devices using radioactive sources should be treated as an important feature to an adequate safety approach during the whole operational life of these equipment, mainly taking into account the extreme conditions of the places where the devices are installed, as shown in figure 1. Thus, the agreement with these standards should be included as part of the equipment specification to the licensing process, however, most nucleonic gauges in Brazil were installed in the period prior to the issuance of these international standards.

Fig. 1 - Nuclear gauges in radioactive facility.

OBJECTIVES AND METHODOLOGY

This work aims to evaluate the nuclear gauges with embedded radioactive sources. It was studied the performance of their shielding design, with the determination of exposures during operation and maintenance situations, taking into account international standards concerning the constructional requirements and classification of nuclear gauges. (IEC62598-2011). In the table 1 it is presented a categorization of nuclear gauges according its dose rates in different distances, as shown in figure 2.

	Dose rate class						
	1	2	3	4	5	6	7 or E
Maximum dose equivalente rate at a distance of 5 cm	Not in compliance	> 1 mSv/h ≤ 5 mSv/h	> 0,5 mSv/h ≤ 1 mSv/h	> 0,05 mSv/h ≤ 0,5 mSv/h	> 7,5 µSv/h ≤ 0,05 mSv/h	> 3,0 µSv/h ≤ 7,5 µSv/h	≤ 3,0 µSv/h
Maximum dose equivalente rate at a distance of 100 cm	Not in compliance	> 0,1 mSv/h ≤ 0,5 mSv/h	> 25 µSv/h ≤ 0,1 mSv/h	> 7,5 µSv/h ≤ 25 µSv/h	> 2,5 µSv/h ≤ 7,5 µSv/h	> 1 µSv/h ≤ 2,5 µSv/h	≤ 1,0 µSv/h

Table 1 – Classification of nuclear gauges into dose rates classes.

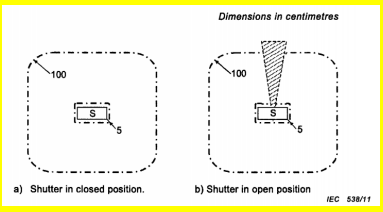
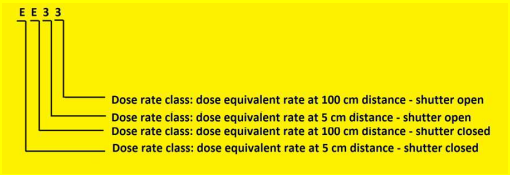


Fig. 2 - Schematic representation of isodistance gauging faces.

The IEC6258 standard presents a classification code with four characters indicating the gauge category, taking into account the dose rate class, as presented in table 1.



Initially, considering 1 Ci (37 GBq) maximum capability, it were analyzed seven nuclear gauge designs, as shown in figure 3. Each one identified by a letter of the alphabet, A, B, ... and G, respectively. The designs were simulated using GEANT4 Monte Carlo program, as shown in figure 4 (a). The positions where the equivalent dose was estimated is shown in the figure 4(b).

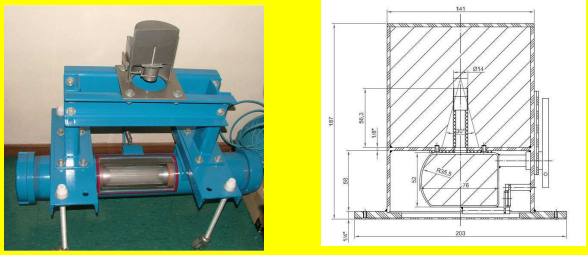


Fig. 3 - Nuclear gauge design.

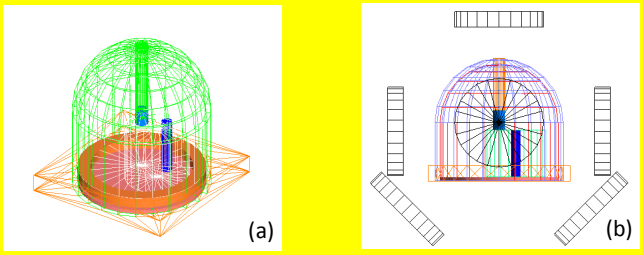


Fig. 4 – (a) Nuclear gauge modeled in GEANT4 and (b) Positions where the dose rates were estimated by Monte Carlo.

CONCLUSIONS AND RESULTS

The simulated results obtained are presented in table 2 and, in the next stage of this study, they will be compared with experimental measurements performed in industrial facilities.

These results point out to allow the establishment of a methodology to assess, during the licensing process, the radioactive facilities using nuclear gauges, as well as the establishment of a better frequency to the regulatory inspections, based in its dose rate categorization.

It should be emphasized that this methodology can point to that older nuclear gauges, still installed in the country, some with over forty years, should be decommissioned.

	DOSE RATE CLASS						
Shutter position	1	2	3	4	5	6	7
5 cm - closed			F	A,D,G		B	C ,E
5 cm - open		F,G		A,D	B,E		C
100 cm - closed		F			G	D	A ,B,C,E
100 cm - open			F,G	B	A,D		C,E

Table 2 – Results to simulated models.

The IAEA-TECDOC-1526 recommends inspection frequencies between 3 and 5 years for nuclear gauges facilities. The results obtained in this study can enable the establishment of a safety indicator tool, so, this additional parameter can be used to determine and to optimize the frequency of regulatory inspections at these facilities.

The classification code point out that nucleonic gauges are classified in the categories related in table 3, and we can concluded that:

- Facilities using F and G models must undergo regulatory inspections in a shorter time interval;
- A, B, D and E models could be inspected in time intervals between 3 and 4 years;
- C models could be inspected every 5 years.

NUCLEAR GAUGE	CLASS (IEC62958)
A	4745
B	6754
C	7777
D	4645
E	7757
F	3223
G	4523

Table 3 – The gauges class