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RADIOLOGICAL SECURITY EVOLUTION OF GAMMA RAY RADIOGRAPHY EQUIPMENT ACCORDING TO CURRENT REGULATORY REQUIREMENTS IN BRAZIL

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ABSTRACT

The Nuclear and Energy Research Institute (IPEN), in accordance with the attributions given by the National Commission of Nuclear Energy (CNEN), has been supplying the market with radioactive sealead sources of Iridium 192 (^{192}Ir), for Brazil and some South America Countries, for more than 24 years. In this period, it has accompanied the evolution of the technological improvement of the used equipment in industrial gammagraphy; in the Sealed Sources Production Laboratory (LPFS). Of the set of operations carried through in the LPFS, since the assemblies, tests of qualification of the sources also inspect at of the equipment for posterior release in applications in field, it is intended to demonstrate to the technological evolution associate to the radiological and operational security. In this work, the data base of the system of the LPFS system will be used, as well as the professional experience of the laboratory team in the daily relationship with the companies responsible for the equipment operation.

1. INTRODUCTION

Based on the necessity of the national market and the technological advances, the National Commission of Nuclear Energy (CNEN), took the initiative to develop radioactivy sources for industrial gammagraphy, due to the increasing industrial technological demand and scientific and normative requirements. With regard to improvements and agility in the not-destructive assays, they are becoming more trustworthy.

In this period, some types of gamma ray radiography, also known as projectors, have appeared providing a better shield and the systems, overcome constraints such as security and conditioning to avoid the source exposition, thus allowing reduced radiological effect (dose rate).

The companies which work with sources of ^{192}Ir (Iridium), are under standards of the CNEN – 6.04 [1], Standards and the complementary Standards CNEN - NE – 3.01 [2], 3.02 [3], 3.03 [4], 5.01 [5] and 6.02 [6], being imperative the fulfilment of the totality of these standards, for the maintenance of the Operation License.

The operation in closed installations or field, all companies must obey in relation the equipment item 5.4 of CNEN - NE- 6.04 [1] Standards, referring maintenance. The equipment of industrial gammagraphy must be inspected regarding: internal tube, identification, equipment shield, extremities covers, handles for transport, constraints systems, pointers of

source position, systems to couple with the remote control, efficiency of the shield and state of the set general conservation and functioning.

The tests were verified by the LPFS equipament at IPEN/CNEN-SP, for industrial gamma radiography with sources of ^{192}Ir, and certificate of inspection with validity of one year or to each exchange of source was emitted.

The inspection comprises the state of conservation of the projector and accessories (remote control and pipe guides), requiring legibility in the serial number, of the model, name of the owner company, international symbol of radioisotope radiation, maximum capacity of the projector and "RADIOACTIVE DANGER" label.

Of the set of operations carried through in the LPFS, since the assemblies, tests of qualification of the sources also inspect at of the equipment for posterior release in applications in field, it is intended to demonstrate to the technological evolution associate to the radiological and operational security.

2. METHODOLOGY

From the bibliographical survey of CNEN Standards and database of the LPFS, associated with the professional experience of the Laboratory Team, who produce sealed sources of ^{192}Ir, at IPEN, to search for the technological advantages and disavantages, the projectors efficiency and the maximum capacity of shield indicated by the manufacturer some outline .

This efficiency was evaluated from collected information random of the LPFS database, in which the exposition rate inside of the limit specified by the manufacturer was projected; the exposition rate in the surface of the equipment is not allowed to be greater than 20 mSv/h, according to the Transport Standard of radioactive sources packaging.

The calculations of the values will be obtained through simple formularizations, to project the limit of activity indicated by manufacturer. Equation (1) was used for each resulting value from the database.

$$RPE_n = \frac{AIM.RME_n}{ASSC} \quad \textbf{(1)}$$

RPE_n – Rate of Projected Exposition n
RME_n – Rate of Measured Exposition n
AIM – Activity Indicated by the Manufacturer
ASSC – Activity of the Source Supplied to the Customer
n – number of the sample

Followed by the average of all obtained values equation (2).

$$RPE_f = \frac{\sum RPE_{1\cdots n}}{n} \quad (2)$$

RPE_f – Final Rate of Projected Exposition

RPE_n – Rate of Projected Exposition n
n_s – number of samples

The efficiency for each projector was obtained by equation (3):

$$E = \frac{RPE_f}{REAS} \quad \textbf{(3)}$$

E – Efficiency (%)
RPE_f – Final Rate of Projected Exposition
REAS - Rate of Exposition Allowed by the Standard

3. TECHNOLOGICAL EFFICIENCY OF THE GAMMA RAY RADIOGRAPHY EQUIPMENT

Table 1 shows the advantages and disadvantages of each equipment. As well as in Table 2 and Figure 1, it be observed the efficiency of the exposition rate in relation to the allowed maximum activity for each projector, where the exposition rate for sources transport in projectors, according to the CNEN Standard is 20 mSv/h in the surface. Each equipment has positive and negative characteristics; the Tech/Ops 660 (T/O 660) and all its subsequent line shows excellent shield and the channel is in "S" form, not presenting risk of source exposition. Its system of security shows two parts: the lock and the remote control connection. In the remote control there are three positions: 1) the position "Lock", where the source is constrainted together with the lock, 2) "connect", where the remote control is connected and, 3) the position "operate", where the source is displayed. This projector has capacity for 3.7 TBq, in its new versions T/O 660B – 5.18 TBq, AM 660 – 3.7 TBq, 880 SIGMA – 4.81 TBq and 880 DELTA – 5.55 TBq; they are very resistant and with low wear, at the moment of the equipments inspection.

The 880 Sigma and Delta models, series T/O 660, of recent manufacture had increased their capacity for 4.81 TBq and 5.55 TBq, respectively, aiming a resistant equipment and low maintenance. The latest innovations is a third of the security system is a lateral constraint that hinders the source exposition, even in the position "operate", and a fourth security system in the back equipment, which without the connection of the pipe guide hinders the exposition source.

The equipment T/O 616, different from T/O 660, with has source capacity up to 7.4 TBq is extremely safe, not needing remote control and pipe guides. It uses instead a pneumatic system, in the superior part of the projector, that when activated, dislocates the source from the guard position of the shield to the central position of the projector, where there is a window for exposition of the radiation beam. In this equipment there are two systems of security, namely: 1) the lock that hinders the source use and, 2) an internal system, that in the eventual faulty of pneumatic system, dislocates the source for guard position in the shield. Its disadvantage is the easy source removal.

The Iriditron 520 projector shows an only system of security, the lock, that constraint the source. This projector, according to the manufacturer supports sources up to 4.44 TBq, however in the replacement of the source in the LPFS, never supported this activity. The

equipment with channel in “S” form presents easy operation, exception for some cases whem undercurrent showed wear of channel. There are cases of projectors which had undercurrent some type of accident, what limited its capacity for sources with activities under 1.11 TBq. The wear of the channel does not have influence in this limitation. They have the disadvantage of easy removal of the source.

Table 1: Projectors with technological advantages and disadvantages.

Projectors	Capacity (TBq)	In Use	Advantages (+) / Disadvantages (-)
AM 660 T/O 660 T/O 660B	3.7 3.7 5.18	Yes	+ Excellent shield, low maintenance, excellent security systems.
880 Sigma 880 Delta	4.81 5.55	Yes	+ Excellent shield, low maintenance, excellent security systems.
T/O 616	7.4	Yes	+ Excellent shield, low maintenance, excellent security systems. - Easy removal of the source.
Iriditron 520	4.44	No	+ Easy operation, low maintenance. - Easy removal of the source, only security system, inefficient shield.
GI 100SA GI 35	3.7 1.295	No	- Easy removal of the source, only security system, channel in “S” much accented.
Gammamat TI-f Gammamat TI-ff	3.7 7.4	Yes	+ Excellent shield, excellent security systems. - Straight tube, fast wear of the security systems.
Gammamat TSI 3/1 Gammamat TSI 5/1	81 4.995	Yes	+ Excellent shield, excellent security systems.
Gammamat – Crawler	2.96	Yes	+ Excellent shield, excellent security systems.
Nuclear Ibérica – 202	3.7	No	+ Excellent shield, excellent security systems. - Wear of the security systems, channel in form of the “U”.
SPEEC-2T	7.4	No	+ Easy operation, low maintenance. - Easy removal of the source, only system of security, inefficient shield.
Teletron SU 100 Teletron SU 100(B) Teletron SU 100N Teletron SU 100V-N Teletron SU 50	5.92 3.7 4.81 5.92 3.7	Yes	+ Excellent shield, low maintenance, excellent security systems. - Straight channel, with oxidation of Uraniun (the loss of tail or stopage of the systems of security of the projector), equipment shows general wear due so its age.

The Gamma Industries GI-100 SA (3.7 TBq) and GI-35 (1.295 TBq) projectors present only one system of security (the lock), although their shield is efficient, they are a very restricted equipment in relation to the displacement of the source in their interior. Therefore with minimum variations of the original position of the source, the exposition rate in its surface is significantly modified. These equipment present channel in “S” form very accentuated, being that with minimum joint alterations (remote control, projector and pipe it guides), presents great difficulty of source exposition. They have the disadvantage of the easy source removal.

The Gammamat TI-F (3.7 TBq) and TI-FF (7.4 TBq) projectors, exception for having undergone some type of accident or wear, are reusable, and present excellent shield. These equipment possess two security systems: the lock and the hook of the remote control for

source exposition. These projectors are small and portable, but they present significant wear of the security systems, being necessary the source exchange, a previous maintenance. The projectors that come with spends sources for the LPFS, in previous inspection were observed to present considerable mechanical wear. Having straight channel, is equipment requires attention, not only for the possible direct beam exposition of radiation emitted has the source, as well as for error of operation or fails of the security systems, since the source can easily leave the projector and be displayed.

Table 2 - Efficiency of the projectors in relation of exposition rate.

Projectors	Capacity (TBq)	(mSv/h)	Efficiency
T/O 660	3.7	12.3	163%
880 Sigma	4.81	8.8	226%
880 Delta	5.55	8.8	227%
Iriditron 520	4.44	22.5	89%
GI 100SA	3.7	18.7	107%
Gammamat TI-f	3.7	10.4	193%
Gammamat TSI 3/1	2.997	5.3	374%
Gammamat TSI 5/1	4.995	7.7	259%
Gammamat – Crawler	2.96	18.0	111%
Nuclear Ibérica – 202	3.7	9.4	213%
SPEEC-2T	7.4	30.3	66%
Teletron SU 100	5.92	18.6	107%

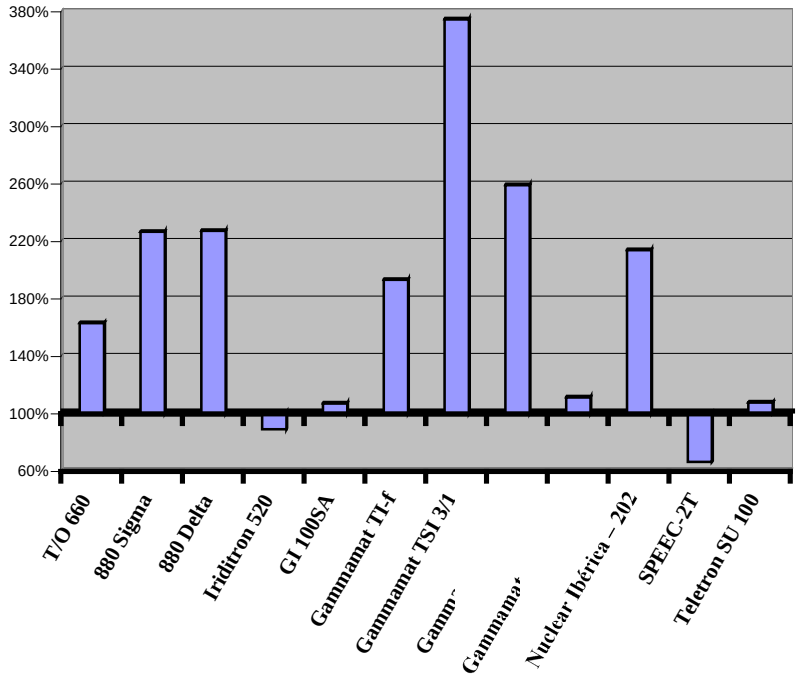

Figure 1 - Efficiency of the projectors in relation to exposition rate.

Equipment manufactured recently, Gammamat TSI 3/1 (2.997 TBq) and TSI 5/1 (4.81 TBq) in relation to Gammamat TI-F and TI-FF, present improvements such as: channel in “S” form, front and back security systems. The front system need of the connection the pipe guides. The back security systems consists of lock, remote control connection and a constraint in the superior part, whichs leave the source, when too many systems are connected correctly.

The Gammamat Crawler projector has a similar system to the T/O 616, where the source is positioned in the inferior part, of guard in the shield. In this case, it does not need remote control and pipe guides. Its capacity is 2.96 TBq and instead of pneumatic system, an electronic device is used, which displays the source in the superior part of the projector. There are two systems of security: 1) the lock, which hinders the drive of the electronic system and the consequent exposition of the source and, 2) an internal device, in case of a possible fail of the electronic system, the source returns for the position of guard in the shield.

The Iberica Nuclear 202 projector, capacity of 3.7 TBq presents an excellent shield. There are two systems of security: the lock and a system of remote control connection, without which the exposition of the source is not possible. This system of constraint always present problems of operation, when inspected. Generally, the maintenance of the equipment is necessary. Its channel in “U” form, is problematic, by the fact that the channel is very accentuated; any mechanical wear of the equipment, causes difficulties of operation.

The SPEEC-2T projector presents an only security system, the lock, that constraint the source. This projector, according to the manufacturer supports sources up to 7.4 TBq. The higher exposition rate in this equipment is due to deficient shield. It is an equipment with channel in “S” form low accentuated, presents easy operation and it has the disadvantage of the easy source removal.

The projectors Teletron SU-100 (5.92TBq) and SU-50 (3.7 TBq) present excellent shields. There are three systems of security: 1) lock, 2) remote control connection and, 3) pipe guide connection. Without these combinations, it is not possible to display the source. The holder of this equipment is reusable. This shield is natural Uranium and after certain period of use some become oxidate, not being possible its disassembly and reuse. These projectors have its natural Uranium straight channel displayed, together with the system of internal closing; without use in humid conditions for some time, it tends to oxidate and hinder the operation system. Despite currently functional, the mechanical wear is visible, being necessary rigorous attention to inspects them. Following the Gammamat series possess straight channel, when the system is opened, the source presents a beam of direct exposition in its front and, in fail of operation or of the security systems, it can allow the source to leave the projector, being able to cause an incident or accident with the exposition to the workers.

The efficiency results, according to Table 2 and Figure 1, show that projectors with values below 100%, do not support the maximum activity of the radioactive source specified by the manufacturer. Equal or superior values to 100% show that the projectors have reached the efficiency indicated by the manufacturer. The projectors with recent technology present a very superior efficiency, with values up to 374%.

4. CONCLUSION

The information from Table 1 confirmed that the current equipment presents better security systems, guaranteeing that even with handling of not authorized people, the access to the

radioactive source is difficult, besides presenting a low rate radiological exposition during the transport and the use. The old equipment, out of operation, presented limited security systems, according to the limited security system, according to the inspections by the LPFS at the IPEN.

Regarding efficiency of the gamma ray radiography equipment it is observed that the Iriditron 520 and SPEEC-2T are below the foreseen, by the manufacturer. The remaining equipment reached the efficiency foreseen by the manufacturer, having outcome the current equipment, with efficiency above other projectors.

The technological evolution of the gamma ray radiography equipment, has brought considerable improvements, as to in the attendance of the CNEN Standards, as well as in the transport and operational security.

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