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C-188 CO-60 SOURCES INSTALLATION AND SOURCE RACK LOADING OPTIMIZATION PROCESSES IN A GAMMA IRRADIATION FACILITY

Paulo de S. Santos[1] and Pablo A. S. Vasquez[1]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
psantos@ipen.br
pavsalva@ipen.br

ABSTRACT

Since 2004, the Multipurpose Gamma Facility at the Nuclear and Energy Research Institute has been providing services on radiation processing for disinfection and sterilization of health care and disposable medical products as well to support research studies on modification of physical, chemical and biological properties of several materials. Recently, there was an increment in irradiation of the Cultural Heritages. This facility uses C-188 double-encapsulated radioactive Cobalt-60 sources kwon as pencils from manufactures outside of country. The activity of the cobalt sources decays into a stable nickel isotope with a half-life around 5.27 years, which means a loss of 12.3% annually. Then, additional pencils of Cobalt-60 are added periodically to the source rack to maintain the required capacity or installed activity of the facility. The manufacturer makes shipping of the radioactive sources inside a high density container type B(U) , by sea. This one involves many administrative, transport and radiation safety procedures. Once in the facility, the container is opened inside a deep pool water to remove the pencils. The required source geometry of the facility is obtained by loading these source pencils into predetermined diagram or positions in source modules and distributing these modules over the source rack of the facility. The dose variation can be reduced placing the higher activity source pencils near the periphery of the source rack. In this work are presented the procedures for perform the boiling leaching tests applied to the container, the Cobalt-60 sources installation, the loading processes and the source rack loading optimization.

1. INTRODUCTION

The cobalt-60, or ${}^{60}_{27}\mathrm{Co}$, nowadays is the widely used gamma radiation source to industrial irradiation processing. It is produced by irradiation, in a nuclear power reactor, of pellets made of cobalt sintered powder welded in Zircaloy capsules, for about two years. When the irradiation finishes, the pellets are further encapsulated in tubes of anticorrosive stainless steel. It is known as ‘source pencil’, a sealed radioactive source [1]. Its usual design, made by Nordion™, is the model C-188.

When used in industrial gamma facilities, the source pencils are placed in source modules (magazines), which in turn are placed in racks. This structure is shown in Fig. 1. The required source geometry is obtained by distributing the source pencils in specific positions of these modules over the source rack of the industrial irradiator [2].

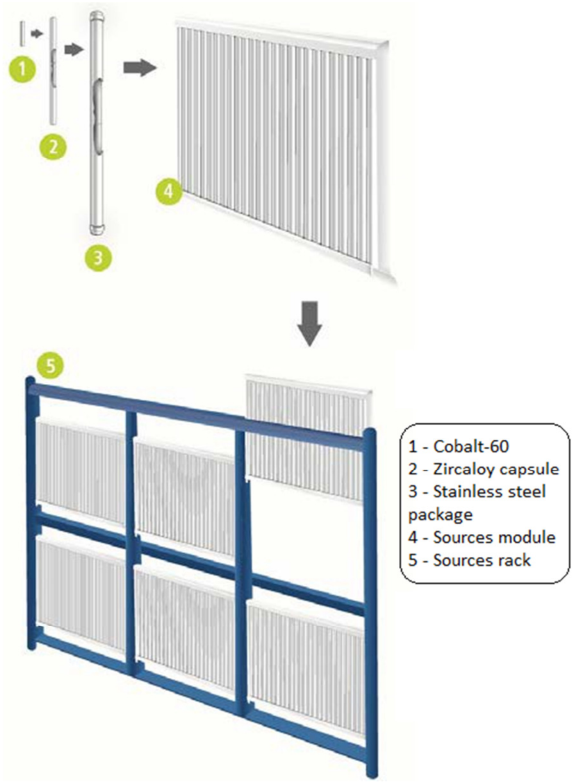

Figure 1: Arrangement of sources in a gamma industrial facility (1)

When it comes to Gamma Irradiation Facility from CTR-IPEN-CNEN/SP, known as Multipurpose Irradiator, it is located in São Paulo University (USP) campus, São Paulo city, Brazil. It is a Category IV irradiator, by Atomic Energy International Agency (AEIA) [2], and Group 1 by (Brazilian) National Commission of Nuclear Energy (CNEN) [3]. This facility, made by Radiation Technology Center of IPEN-CNEN/SP, and financed by FAPESP under the project number 1997/07136-0, runs since 2004. It is controlled by PLC system. It runs in the stationary or continuous mode, depending on the purpose of irradiation; its full capacity is either 8 m^3 in stationary mode or 16 containers with 0.27 m^3 each in continuous mode. Its full capacity of carrying is 504 cobalt-60 source pencils; but nowadays, it has 52 source pencils.

2. THE LOADING PROCESS

The loading is a very important process to the factory. Since the beginning of operation, had been made three loadings in the Multipurpose Irradiator. But it never had been documented.

Due to the half-life of cobalt-60, about 5.27 years, there are losses in operational capacity. It happens because the dose rate decreases with the time, increasing the irradiation time. Therefore, it is important purchase new radioactive sources to keep the radioactive activity at the same level. Unfortunately, source pencils to Industrial Irradiation Facilities are not produced in Brazil, yet; then, the import is necessary. There are some manufacturers in Canada, Russia and Argentina, whose cobalt-60 price is between US$ 2.50 and US$ 3.50 for each 37 GBq (or 1 Ci) of activity.

Before the loading it is important to plan the distribution of sources to decrease the Dose Uniformity Ratio (DUR, ideal value: 1). A way to get it is placing the higher-activity source pencils near the periphery of the source rack (source augmentation) [2].

2.1. The Sources Carrying and Receipt

The receipt of radioactive source pencils takes place after a longer administrative process that includes public international auctions and strategic transport plans of radioactive materials. In this plan are included IAEA and CNEN standards. The source pencils are carried in a containment system, a packaging specified by the designer as intended to retain the radioactivity of the sources during transport [4] [5].

The containment system has a certificate approved by regulatory authority from each country that takes part of process. The one is made with high atomic number elements as lead, tungsten and depleted uranium [6]. Its aim is to shield the gamma radiation, to maintain the radiological security conditions near the package. The cobalt-60 source pencils can be take out from containment system under the irradiator pool (by submersion) using adequate tools, including specific telemanipulators. The irradiator pool, with 7 meters of deepness, gives an additional shield to operators. Moreover, a mobile crane is necessary to handling operations, due to the package's weight, around 7 tons [1].

2.2. The leakage test of the sources

It is the first procedure to ensure that there is no radioactive material leakage. The containment system has two valves, one to water inlet at bottom and other to water outlet at top. Using a feed water system, which works by gravity, the water is introduced into the containment system. At water outlet is put a filter paper to retain any material particle that could be brought by the water vapor produced. It is shown in Fig. 2. After that, the water is drained of the system and subject to radioactive contamination tests. Then, the containment system is released to be submerged in the irradiator pool [7].

Figure 2: Leakage test of radioactive material

2.3. Preparing to install and containment system submersion

Before the containment system submersion, it is important to remove the metallic structure present inside the irradiation chamber. As well the structures named ‘plug of roof’, which is a concrete cover located at roof of irradiation chamber. It is shown in Fig. 3. Furthermore, is necessary using a crane with experienced operators to handling the containment system and put it inside the pool.

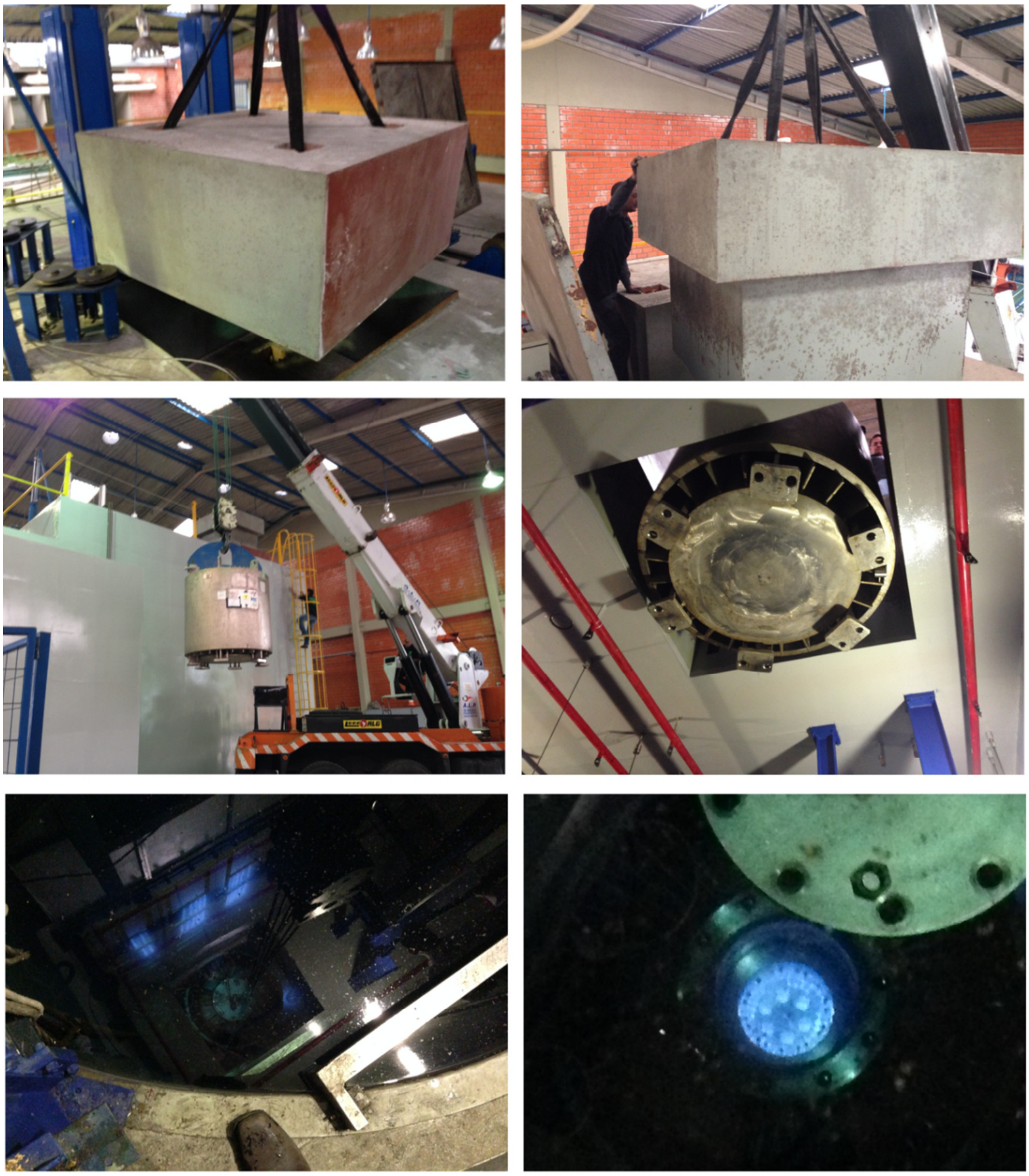

Figure 3: The containment system submersion process in the pool

The plug of roof to weight around 2 tons, and is divided in two parts coupled with each other. Before the lifting of this one, it is necessary take off some of the cover screws of the containment system. The others one can let loosed. After, the loosed screws going to be take off with specific tools.

When the space is free, the containment system is submersed in the pool by the crane. When the one is at bottom, the tungsten cover is removed and the sources conveyor is taken off. Finally, the containment system is removed from the pool to return to the sources manufacturer.

2.4. Sources installation on the racks

The sources handling is made over a submersed table placed inside the pool. The modules are taken off from the racks and placed on the table and unlocked to do the loading. Following a previous evaluated sources distribution map [8] [9] [10], the sources are retired from conveyor and installed in the module, one by one. It is according the serial number given by manufacturer. The spaces between the sources are filled by 'dummies', which are empty sources packages. The process is shown in Fig. 4.

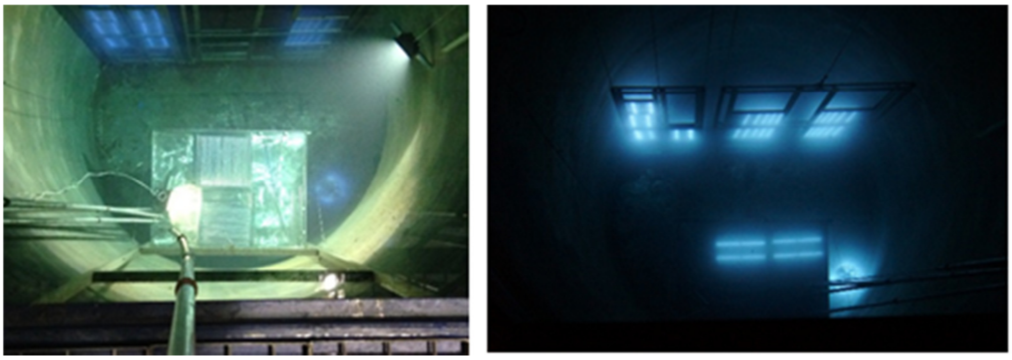

Fig. 4: Module being handling with telemanipulator tool

Lots of tools can be coupled to the telemanipulators. For example screwdrivers, nut drivers, tweezers, shovels and hooks, as is shown in Fig. 5.

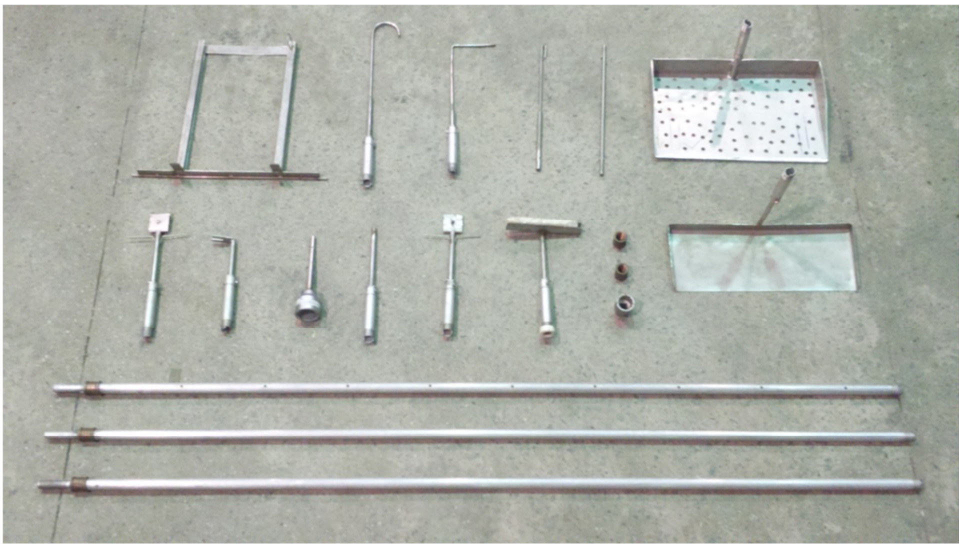

Fig. 5: Telemanipulators and tools used to sources loading

At the end, the modules are installed in the planned sequence in the racks and the internal structures of the irradiation chamber are reassembled. Moreover, it is important to make some operational and radiological security tests. It is to ensure the security of the factory.

Empirically, was verified that are spend around ten days to install twenty cobalt-60 sources, including the time spent to move the already installed sources and the dummies.

3. CONCLUSIONS

Can be observed that the process require six Radiological Security standards, at least. It shows the complexity of the loading process to ensure that there is no risk for the currently operations, despite of the apparent simplicity of the process. This work showed a description of the loading process, in such way that can be a reference to an eventual installation manual for the cobalt-60 radioactive sources.

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REFERENCES

1. Santos, P. S. *Estudo e Otimização dos Parâmetros de Processamento por Radiação Gama em Escala Industrial Considerando Fatores Operacionais.* São Paulo, Brazil. (2017).
2. International Atomic Energy Agency. *Gamma Irradiators for Radiation Processing.* Vienna, Austria. (2005).
3. Comissão Nacional de Energia Nuclear. *Licenciamento de Instalações Radiativas.* Rio de Janeiro, Brazil. CNEN NN 6.02. (2014)
4. International Organization for Standardization. *Transporte de Materiais Radioativos.* Rio de Janeiro, Brazil. CNEN NE 5.01. (1988)
5. International Atomic Energy Agency. *Regulations for the Safe Transport of Radioactive Material.* Vienna, Austria. IAEA Safety Standards Series No. TS-R-1. (2005).
6. International Organization for Standardization. *Radiation protection – Sealed radioactive sources – General requirements.* Geneva, Switzerland. ISO 2919:2012. (2012)
7. International Organization for Standardization. *Radiation protection – Sealed radioactive sources – Leakage test methods.* Geneva, Switzerland. ISO 9978:1992. (1992)
8. International Atomic Energy Agency. *Trends in Radiation Sterilization of Health Care Products.* Vienna, Austria. STI/PUB/1313. (2008)
9. Omi, N. *Geração de um Aplicativo para Simulação de Doses em Sistemas de Irradiação Gama.* São Paulo. Dissertação de Mestrado. (2000).
10. Santos, P. S.; Napolitano, C. M.; Ferreira, D. C.; Medeiros, S. A.; Silva, M. E.; Omi, N. M. Dose Rate Mapping Near the Sources Racks. *International Nuclear Atlantic Conference - INAC 2011.* Recife, Brazil. (2011).