DESIGN AND DEVELOPMENT OF A DEVICE FOR THE OPENING OF IRRADIATED ALUMINUM CAPSULES IN THE IPEN IEA-R1 NUCLEAR REACTOR

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ABSTRACT

The production of radionuclides in nuclear research reactors is an important activity of national nuclear energy programs. Numerous radionuclides produced include molybdenum-99, iodine-131 and phosphorus-32, widely used in medical procedures. Radionuclides are produced by exposing the target material to a neutron flux in one of the irradiation positions in the core of the nuclear reactor. Before irradiation, the target materials must be contained in sealed capsules, preventing the release of radionuclides that contaminate the nuclear reactor installation. The capsules used in the Nuclear and Energy Research Institute (IPEN) IEA-R1 nuclear reactor are made of aluminum, taking advantage of the following characteristics: low cross section for neutron absorption, radionuclide production from the aluminum alloy of short half-life, good thermal conductivity and possibility of cold sealing of the capsule. This work proposes a new device for opening irradiated aluminum capsules (rabbits), with implement of a better procedure, focusing on operator safety. Ensuring safety during all stages and processes is a preponderant factor when it comes to radioactive materials. The following main deficiencies are identified about the current opening procedure: a) radioactive debris generated by the cutting contaminate the environment of manipulation, increasing the risks of exposure to radiation and the care with the collect and disposal of these debris; b) rotation movement of the capsule during opening may cause damage to the target material and its casing, leading release of radioactive target materials. The new opening device: a) uses the least possible electronic components based on integrated semiconductor circuits, susceptible to radiation; b) contemplates that the insertion and removal of the capsules will be done by telemanipulators; c) modifies the type of cutting performed, from abrasive to cutting wheel blade, allowing minimal generation of small size radioactive debris; d) replaces the rotation of the capsule by a movement in the cutting head, keeping the capsule still, thus reducing the risk of damage to the samples; e) provides greater control, process accuracy and emergency stop, through improved remote operating system. Results of comparative tests showed that the current system produces average 0.3(2) mg of debris per cut, while the proposed system of cutting wheel blade presented a reduction of more than 99 % in the generation of debris. In addition, the immobilization of capsule during the open prevents damage to the radioactive target materials.

1. INTRODUCTION

In the Nuclear and Energy Research Institute (IPEN) IEA-R1 nuclear reactor, tubular aluminum capsules are used as a container for target materials. Capsule dimensions are 70 mm in length by 22 mm in diameter as shown in Figure 1. These capsules are manufactured with aluminum alloy 1050 or 1100 [1], are sealed by TIG (Tungsten Inert Gas) welding of a lid, similar to procedures used in other nuclear research reactors [2, 3, 4, 5], and finally tested for leak tightness before irradiation, by hot bath bubbling test [6, 7].

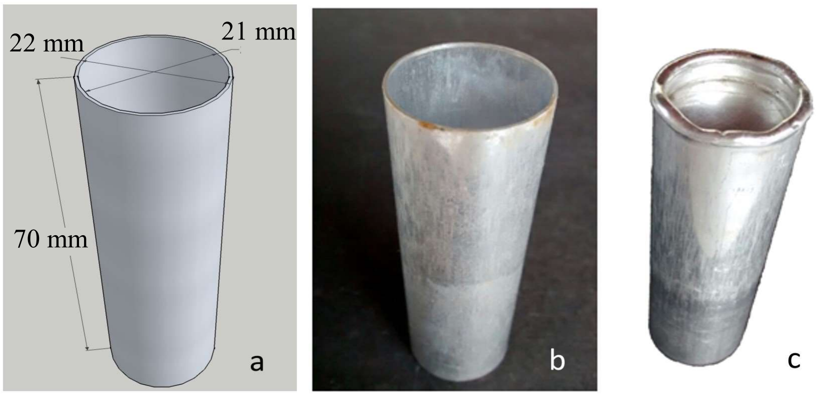

Figure 1: Aluminum capsule used in the IPEN IEA-R1 nuclear reactor. (a) dimensional, (b) real example, (c) with TIG welded lid.

The irradiated capsule is manipulated inside a hot cell, with a 50 mm thickness lead wall. To access the irradiated target material, a capsule opening device is used [3, 8, 9, 10]. The capsule opening devices constitute an important auxiliary equipment used in the process of obtaining the radioactive sources, the equipment and their use has been commonly cited in papers, also being patent objects as in Douis et al., Nakajima and Chistov [11, 12, 13].

These devices consist of aluminum cylinder cutting systems, which traditionally can be performed by abrasion, as the one currently in use at IPEN and others [11]. The advantages of these systems are their simplicity, robustness, low equipment costs and ease of maintenance [14]. On the other hand, the way of the cut is made in the current device, with the capsule being rotated at high speed, can release radioactive target material out of the tube [13], as well as spreading debris from the cut in the hot cell.

The IPEN device, showed in Figures 2 and 3, works as a small lathe. The irradiated capsule is inserted into a holder cast metal cylinder, and then rotates at high speed. A cutting tool, moved by a pneumatic piston, is directed perpendicularly to the capsule, extracts material along the circumference of the capsule, creating a furrow, which increases in depth as the cutting tool advances until the depth of the furrow reaches the thickness limit of the capsule wall, performing the total cut of the upper part of the irradiated capsule.

Figure 2: Opening device. (i) inside hot cell of the Laboratory of Production of Sources for Radiotherapy of the Radiation Technology Center - IPEN, in highlight:

(a) pneumatic piston, (b) cutting tool, (c) hole to insert the capsule (d) telemanipulators; (ii) inside the fume hood of radionuclide manipulation area of IEA-R1 nuclear reactor.

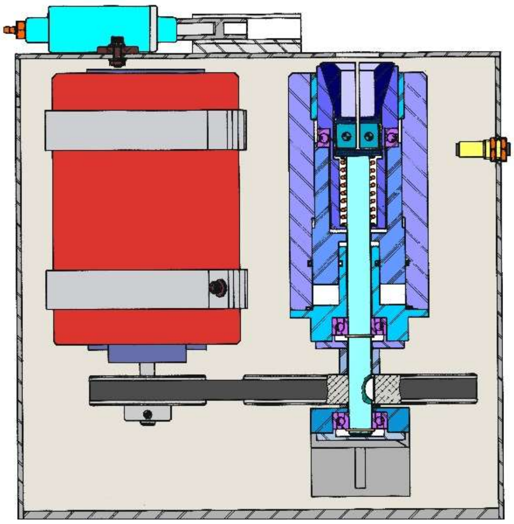

Figure 3: Opening device, side-cut drawing.

The current capsule opening device was manufactured in IPEN in 1989. Although it has served its purpose well over the years, it has some disadvantages, which are:

1) Debris - capsule cutting by the abrasive method of the opening device spreads aluminum alloy residues around the device, contaminating the inside of the hot cell with particulate radioactive material (Figure 4);

Figure 4: Radioactive aluminum debris around the opening device after a cut performed.

2) Pneumatic Piston - the pneumatic piston that moves the cutting tool has only full feed and full retraction steps, preventing the operator from fine controlling the cutting process;

3) Rotation cylinder - the cylinder that makes the capsule rotate has presented problems in the mechanism of centralization, thus, when the capsule leaves the axis of rotation of the cylinder, the cutting tool cannot cut properly, occurring a deformation in the wall of the capsule. In addition, there is no way to verify the correct operation of the holder that fixes the capsule;

4) Volume - the working area of the hot cells are restricted and the opening device could have smaller dimensions optimizing the assemblies of equipment inside the hot cell;

5) Gap - the capsule opening device has a space between its bottom wall and the surface of the hot cell, where small radioactive sources manipulated within the hot cell can lodge, resulting in the need to withdraw the opening device, with possible increase of the dose of the operator. In addition, the cutting residues can enter the mechanism of the device through the hole for insertion of the capsule, inhibiting its perfect functioning.

Another concern is about some solid, liquid, gaseous or powdered target materials are previously encapsulated in containers that ensure a first containment and isolation of the target material, which are subsequently inserted into the capsule. These containers are generally more fragile, usually composed of quartz or aluminum [2, 15, 16, 17].

During the process of the capsule opening, an intense rotation movement, problems of centralization in the holder, the lack of precise control of the cutting tool advance, and of the process of opening, may cause rupture of the container, releasing radioactive target material, contaminating the interior of the hot cell.

The main objective is to design and develop a new opener device for the irradiated capsules that can increase safety for the process, minimizing or eliminating the previously exposed drawbacks.

2. LITERATURE REVIEW

Chistov [13] presents a device to open irradiated targets, usually made of aluminum tubes closed at both ends, which are opened by remote control in armored environments. The device immobilize the capsule and perform a cut without abrasion. The developed device was tested under production conditions, and resulted in minimization of the possibility of material loss during the opening process. The device may be stationary or portable, and is handled by an operator working with single or master-slave telemanipulators. Chistov's opener machine drawing is shown in the Figure 5.

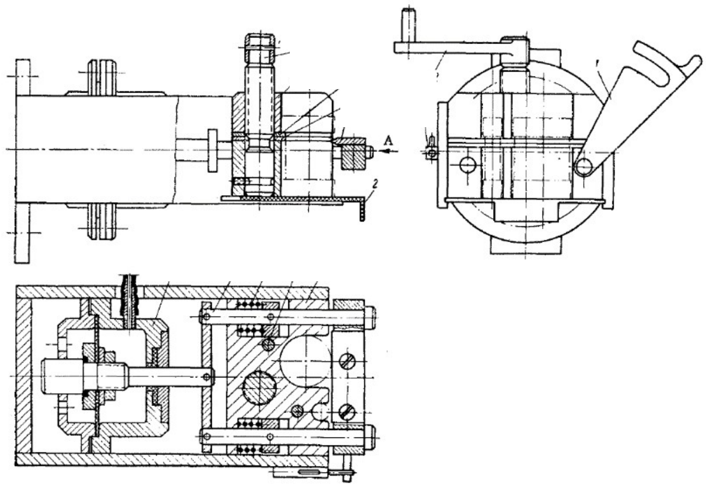

Figure 5: Capsule opening device proposed by Chistov.

Douis et al. [11] propose a patent on a device for opening and remotely handling a container, and in particular an irradiated tube. The device drawing is shown in the Figure 6.

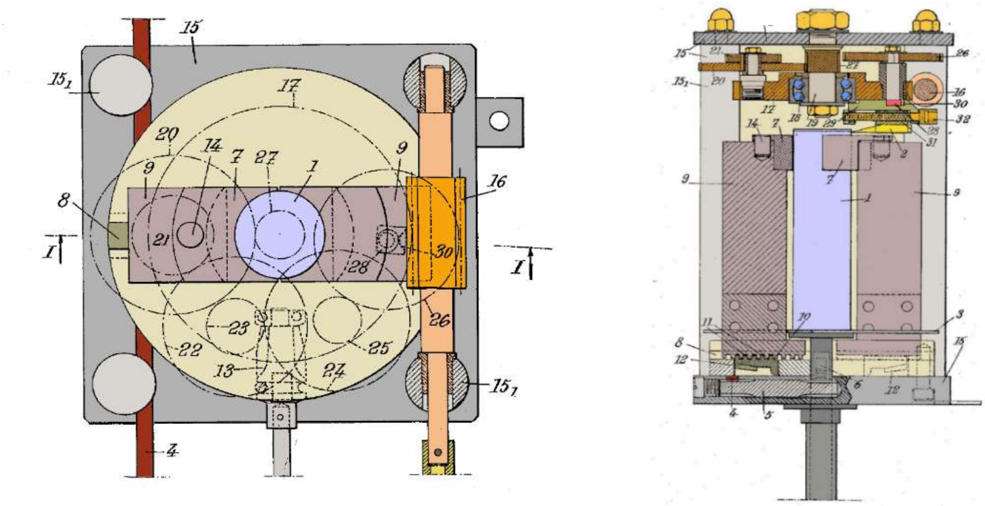

Figure 6: Capsule opening device proposed by Douis et al., top drawing, side-cut drawing.

Among the positives of the device proposed by Douis et al. [11] it is possible to cite the immobilization of the irradiated capsule during cutting since capsule vibration is thus minimized, ensuring greater integrity for the more sensitive samples, such as liquids and gases. Control of the feed of the cutting tool whose feed rate depends on the speed of rotation of the shaft with the endless thread. The production of few debris during the cutting procedure is also cited as a positive aspect, in addition, this debris do not interfere with the cutting mechanism, which is above the cutting tool.

Nakajima [12] proposes a patent for a capsule opener. Each wheel blade is positioned to rotate around the capsule, and also to move radially, to cut the capsule. The capsule, the vertical displacement mechanism, the attachment mechanism and the cutting mechanism are all contained within a housing and are driven by a telemanipulator within a hot cell. The Nakajima's capsule open device drawing is shown in the Figure 7.

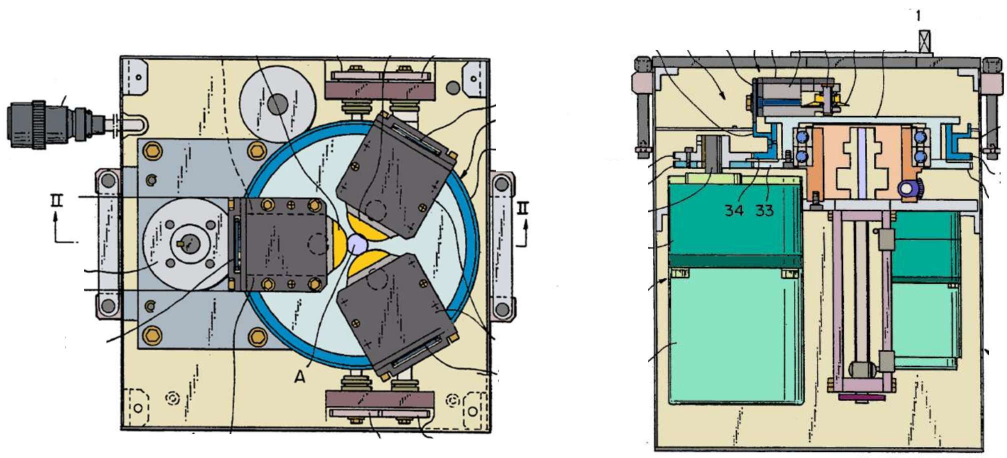

Figure 7: Capsule opening device proposed by Nakajima, top view, side-cut view.

The production of few debris, due to the characteristics of the design, and the isolation of those debris inside the device casing, also immobilization of capsule, are related as positive features of the device.

3. RESULTS AND DISCUSSION

Differently from other devices, as in Douis et al. and Nakajima [11, 12], the mobile mechanical part of the IPEN device lies immediately below the cutting tool where the debris are generated, thus the cutting residues can easily be housed in the mechanical part of the device causing such as loss of centering and incorrect holder of capsules. Mechanical problems coupled with capsule spinning speed can damage the sensitive target materials inside the capsule and perform a defective cut.

Bench tests using cutting tool of the current system attached to a lathe (Figure 8), which simulates the opener device mechanism, produce an average of 0.3(2) mg of debris per cut, with wide variety of lengths, from less than 1 mm to 5 mm, and some tubes collapse if it is not properly fixed and centralized. Another cause for the collapse of the capsule wall is due to the high speed of rotation associated with the fast advancement of the cutting tool.

Figure 8: Cutting tool test, tool aspect (left), making a cut (right).

The same tests by changing the cutting tool by wheel blade (Figure 9) shows a reduction of debris more than 99 %, and the debris particles sizes are smaller than 0.1 mm. In addition, when the cutting disc was advanced rapidly, there was a small deformation in the wall of the capsule, causing burrs internally.

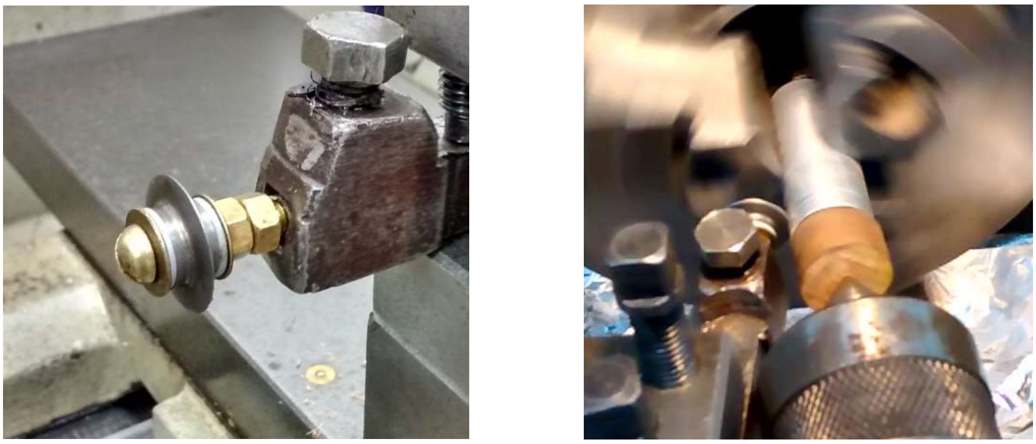

Figure 9: Wheel blade test, tool aspect (left), making an opening (right).

The wheel blade advance rate should be slower, and the opening made by a cutting head can be performed at low rotational speed, thus we can use these features to promote greater control and safety for the opening process. Moreover, for better accuracy of the opening, more than one wheel blade can be used as seen in opening device proposed by Nakajima [12].

From the machines studied as a reference and the type of cut made by cutting wheel blade, the following design was presented for a cutting device to be implemented in IPEN. The opener device proposed, drawing in the Figures 10 and 11, has the following characteristics: remotely controlled, the capsule stands fixed and immobile locked by pneumatically operated tabs.

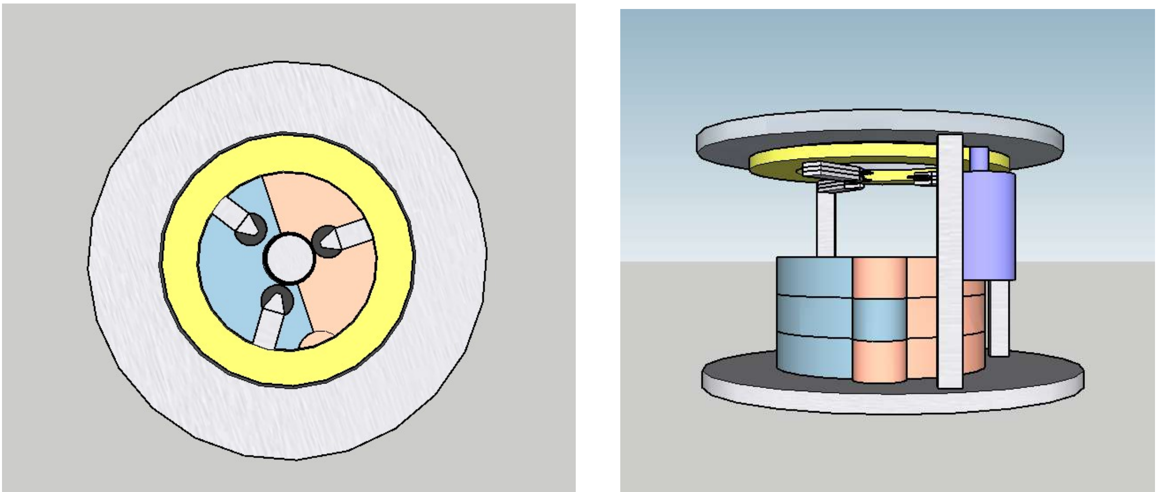

Figure 10: Design of capsule opening device, top drawing, side drawing.

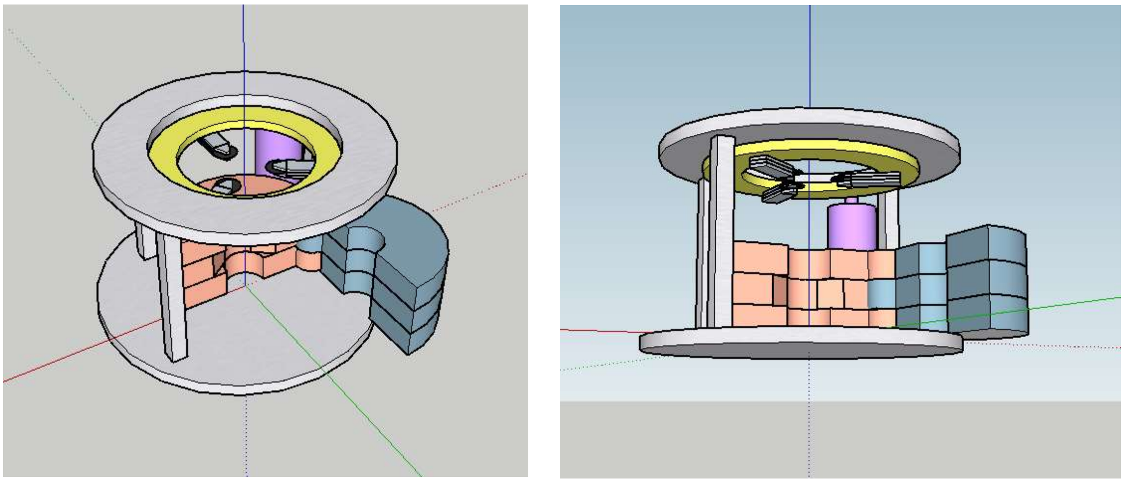

Figure 11: Design of capsule opening device, top perspective with tabs open, bottom perspective with tabs open.

A cutting head in upper position, containing three wheel blades, moves with low rotation around the capsule meanwhile the three wheel blades holders advance radially to the center, opening the capsule. The device is opened to facilitate the visualization of its correct functioning, cleaning and maintenance of the internal parts. The motor is connected directly to the cutting head, reducing the amount of moving parts. The tabs have large apertures and recesses to facilitate handle with telemanipulators.

The detailing of the parts of the opening device designed is shown in Figure 12.

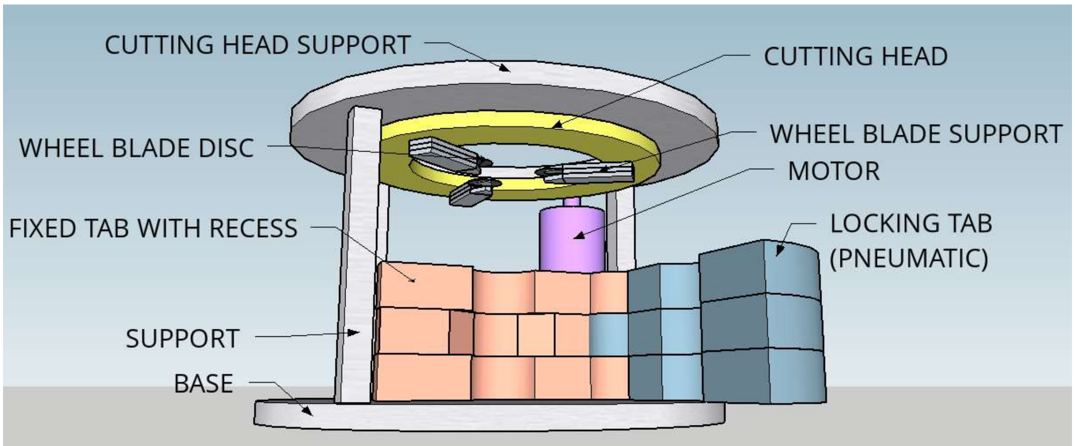

Figure 12: Design of capsule opening device, parts indicated.

4. CONCLUSIONS

The opener device designed have tabs to fix the capsule during the opening, thus increasing safety, mainly when liquids and gaseous samples are manipulated, is also have compact shape, with few moving parts being accessible to easy clean, ensure improvements over the currently model used.

The method of cut by wheel blade, minimizes the debris around the device, and makes easier to clean. In addition, the wheel blades are mounted in the cutting head wich is positioned above the capsule, avoiding to debris causes mechanism malfunction.

The method designed for advance of wheel blade, plus the low speed of the cutting head and immobilization of the capsule, ensure more accuracy, control and safety for the opening process.

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