A proposed Design of Mechanical System of Industrial Cobalt $^{60}$ Irradiation Facility

A. B. Keshk* and B. W. A. Abo-Shosha**

* National Center for Radiation Research and Technology Atomic Energy Authority  
** Arab Academy for Science, Technology AND MARI Time Transport  
E-mail: afifibelal485@gmail.com  
Received: 19/10/2010. Accepted: 06/12/2010.

ABSTRACT

Irradiation processing of industrial gamma irradiation facilities by Co $^{60}$ irradiator (wet-storage) maintained success. Active results were recorded through performance of irradiation processing parameters through new modifying the mechanical systems components of irradiation facilities. Some accidents and negative results were recorded after these modifications like the source rack jamming when product boxes were pushed by mechanical pushers system. That led to radiation source assembly did not falling down to the shielded position inside the storage pool. Ozone concentration levels inside irradiation room exceed the international standards because of increasing source activity and decreasing air volume of irradiation room. The work shows the necessity need to design new mechanical systems where the first will trance the four shelves which are carried by cracked and deforced boxes far away from the two sides of shroud and radiation source. The second system will push a calculated air volume inside irradiation room, to increase average of air volume change each hour inside irradiation room for decreasing ozone concentration. The fan of the mechanical ventilation system operates when radiation source is up and down to reduce ozone concentration inside irradiation room when the source is down.

Key words: Sodium Industrial irradiation facility, mechanical systems components, encapsulation radiation source rack, ventilation system, ozone concentration.

INTRODUCTION

About 170 designs of industrial gamma irradiation facilities using Co$^{60}$ irradiator (I.V category) wet-storage are used in different countries in
development under the supervision of I.A.E.A. Many successes are maintained by using this irradiation processing (cold) sterilization in various fields such as sterilization of medical and pharmaceutical products Fig. (1-3). Most of facilities components were modified like the rack of encapsulated design radioisotopes, Product boxes, and product carrier. The source storage pool were lined with a stainless steel liners, the source activity were increased and two source racks where used. The mechanical ventilation system operates when radiation source is up and stops when source is down. The total volume of product boxes was increased and the total volume of air inside irradiation room decreased. Active results were recorded of performance of processing parameters \((\text{1& 2})\). Modern control of gamma irradiation facility is maintained with improved safety system \((\text{3})\). Radiation facility safety is maintained through environmental impact assessment to improve environmental protection \((\text{4})\).

Incidents and irradiation accidents were occurred in some of irradiation facilities (inside and outside them). Condition of radiation exposure, environmental pollution, fire inside irradiation room and great damages of irradiation facilities components were caused by accidents effects \((\text{1-4})\).

Workers and some of public were involved in these events \((\text{5, 6 and 7})\) causing injury and danger is a result of:

1. A source jamming, with the source assembly failing to return to its shielded position inside the storage pool.
2. Part of the source assembly being detached and left its rack in an unshielded position.
3. Leakage of source.
4. Malfunction or deliberate defeat of safety control system.
5. Flooded inside irradiation room during fire resistance.
6. Ozone concentration exceeds.
7. Fire inside the shielded room.

**MATERIALS AND METHODS**

In a typical industrial irradiation design; there is an irradiation room inside the plant which is surrounded by calculated thicknesses of concrete barriers and roof (concrete shielding) to prevent radiation exposure of the operators and public. The concrete shielding thickness is determined on the basis of the maximum foreseen activity, and the criterion that radiation levels outside the radiation unit remain lower than the maximum permissible levels. Very often its ventilated irradiation room on conveyer belt which is exposed to irradiation by Co\(^{60}\) source. When the product boxes have been exposed for a
sufficient amount of irradiation period, the source rack is lowered back into storage pool of water. The irradiated product boxes leave the irradiation room through products maze on the mechanical conveyer system. The irradiation processing works are maintained by control panel and operators outside the irradiation unit. When the source rack in the storage pool, it is safe for workers to enter the irradiation facility through the main maze where the main door is opened as shown in Figs (1ad 2).

**Fig. 1 and 2: Schematic diagrams of two irradiation facilities**

CO\(^{60}\) pencils are trance in a shielded container that is lowered inside the storage pool inside irradiation room through hole and ceiling plug, or it is tranced inside the concrete room, through the main door and the legs of main maze in other designs. They are arranged in a source rack, which can be lifted into a radiation room for processing and afterwards lowered back into a storage position at the bottom of a pool of water of 5.5 m or 7.0 m depth depending on the design specifications. During processing the source is stationary and products are tranced on conveyer around the radiation source (Fig 3).

**Fig. 3: Schematic diagram of source rack pencils.**
Work technique:

Some dynamic systems are modified in this work to improve operation of moving bodies (radiation source rack, source hoist mechanism and product transport system) to prevent the stuck of radiation source by jammed product boxes. The new design allows tracing a part of each shelf of the conveyer system which is carried by jammed boxes far away from source rack that leads to safe falling down of the source rack inside storage pool.

A new mechanical system is designed to push a calculated air volume from outside to inside irradiation room to increase air volume changing average each hour that leads to reduce ozone concentration inside irradiation room. The fan motor must be operating directly when radiation source is up or down.

Work Idea:

The new moved part of any shelf of the mechanical system is tranced through a maximum distance equal batch distance (step) maintaining safe transport for the moved part on each side of the conveyor system. It was arranged on the floor of the irradiation room (irradiation room dimension 8.2 m length, 4.2 m width and 3.00 m high).

Radiation safety is maintained through preventing the stuck of radiation source.

To increase the average of air volume change / hour of irradiation room is maintained through pushing calculated air volume inside irradiation room by using pipes system which is passed through electrical cables tunnel. The Egyptian facility is a (multi uses irradiation facility) where air pipes design is passed through tunnel or research trace maze and they are passed, through the main maze legs of Russian irradiation facility, because it has not a main door.

RESULTS AND DISCUSSION

Radiation source mechanism of I.R 206 design.

It is compromised of two vertical mounted source racks designed by two pneumatic hoists. Each hoist, mounted on the shield roof, raises a source rack when the automatic operation starts. The hoist is interlocked with the irradiator control safety system that promptly returns the source rack to storage pool bottom if any system faults are detected. Fig (4).
Fig. 4: Schematic diagrams of two vertical source racks pencils.

The radioactive cobalt$^{60}$ source material is doubly encapsulated in this design where the radiation sources are seals and are inserted into subassemblies called modules. When assembled in the rigid stainless steel source rack. After modification there are two source racks (operated either independently or together)$$^{8}$$.

Each sealed source is identified by an engraved serial member in a module is recorded. Each module has a capacity of 42 sealed sources$$^{9-12}$$.

When fewer than this number are required to make up the desired strength, the remaining spaces are filled with non-radioactive "dummies" each module is closed by a special latch that cannot open while the module is in the source rack figs (3 and 4). The tile of the storage pool was changed to stainless steel liner to provide a leak tight.

The I.R 206 tote irradiator is a roller bed conveyor plant. This irradiator processes totes containing product by exposing them to a controlled dose of gamma radiation. Tote boxes loaded in the storage are automatically conveyed into the radiation room, the source passed mechanism ensures that products boxes receive the required dose. Ozone concentration levels increased depending on decreasing air volume of irradiation room which occupied by added product boxes on the new conveyor system that is located inside the maze legs$$^{13}$$.

The outlet maze conveyor automatically transfers the tote boxes to the irradiation storage area for unloading empty totes are then transferred back to the loading station.
Control system interlocks keep the irradiator from starting up if conditions are unsafe. Problems, or faults, are registered and shown at the PLC control panel and must be corrected before start-up can begin. If a fault occurs during the operation of the irradiator, the source will automatically return to the safe storage position in the pool and all converses will stop. Fig (5).

**Fig (5). Control system of industrial irradiator (J.S 9600).**

**Performances of (J.S 9500 – J.S 9600) designs**

*Processing parameters*

- Product box sizes and percent of total of each.
- Storage requirements.
- Product densities (g/cm³).
- Space allocation.
- Minimum and maximum dose limit.
- Irradiator location.
- Annual volume throughput.
- Future growth.
- Plant operating parameters.
- Packing Efficiency (%)
This represents the ratio of actual product volume inside the design to the represents product stretch volume.

**Dose Uniformity Radio**

This is the ratio of maximum dose received by the irradiated product holdup (m³).

It is the volume of product in the irradiator interim and source pass area of any one time.

The following assumptions are based on:

1. Maximum dose applied to product is 25 k. gy (2 – 5 M.rad).
2. Through put is based on 8000 h/year of irradiator operation.
3. Packing efficiency is 100%.
4. All products in the source pass conveyor are the same density.

**Through put comparison** - 4 pass (case 1) and 8 pass (case 2)

*The results indicated are for purposes of illustration only.*

**Through put comparison** - JS 9500 (case 1) and JS 9600 (case 2)

*The results indicated are for purposes of illustration only.*

Fig. 6: Different source activity, different product density and different dose uniformity.
These cases demonstrate the annual throughput achievable for a product density of 0.1 g/cm$^3$ and source strength of 1.5 million curies of Cobalt$^{60}$ Fig. (6) shows the annual throughput is 38.880 m$^3$ for J.S 9500 (I.R 206) conveyor and 47.590 for a J.S – 9600 conveyor system.

The case shows that the source strength required to process a product density of 0.2 g/cm$^3$ at annual throughput of 70.000 m$^3$ is 2.7 million curies for the JS-9600 irradiator. JS – 9500 is limited to 32.880 m$^3$ / yr with 1.5 million curies.

They show that for a given amount of cobalt$^{60}$ irradiator, throughput is higher in an S- 9600 irradiator than a J S – 9500 irradiator, but this is achieved at the expense of greater product holdup and more totes tables. (1and 2).

Table (1 -A). The main elements of irradiation design J.S 9500 / 9600 (Tote)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Tote volume</th>
<th>Minimum Dose</th>
<th>Product Density</th>
<th>Source strength (curies)</th>
<th>Annual throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.s 9500</td>
<td>52 × 52 × 80</td>
<td>2.5 M.rad</td>
<td>0.1 g/cm$^3$</td>
<td>0.75 × 10$^6$</td>
<td>38.880 m$^3$</td>
</tr>
<tr>
<td>J.s 9500</td>
<td>50 × 60 × 100</td>
<td>25 k. Gy</td>
<td>0.1 g/cm$^3$</td>
<td>1.5 × 10$^6$</td>
<td>38.880 m$^3$</td>
</tr>
</tbody>
</table>

Table (2 - B). The main elements of irradiation design j s 9500 / 9600

<table>
<thead>
<tr>
<th>Unit</th>
<th>Tote volume</th>
<th>Minimum Dose</th>
<th>Product Density</th>
<th>Source Strength curies</th>
<th>Annual throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.s 9500</td>
<td>Varying from</td>
<td>2.5 M.rad</td>
<td>0.2 g/cm$^3$</td>
<td>2.7 × 10$^6$</td>
<td>70.00 m$^3$</td>
</tr>
<tr>
<td>9500</td>
<td>40 × 50 × 80</td>
<td>25 k. Gy</td>
<td>0.1 g/cm$^3$</td>
<td>1.5 × 10$^6$</td>
<td>38.880 m$^3$</td>
</tr>
<tr>
<td>9500</td>
<td>65 × 80 × 145</td>
<td>25 k. Gy</td>
<td>0.2 g/cm$^3$</td>
<td>1.5 × 10$^5$</td>
<td>32.00 m$^3$</td>
</tr>
</tbody>
</table>

Fig. 7-A: The main elements of (JS 6500/6000) design * Tote
The work shows a modified design of the mechanical system that allows trancing away any shelf part or a shelf of the four shelves (2 upper shelves and 2 down) inside irradiation room which are carried by the product boxes far away the two sides of shroud and the source rack (14). The radiation source is prevented of jamming by this modified design that allows falling the source rack to its safe shielded position inside the storage pool. The main door will be opened. The jammed boxed are trance outside the irradiation room the moved parts (New design) will be returned to its normal position on the main shelf. The mechanical system will be returned to the normal irradiation position (Fig 7A and B). Radiation source is raised to irradiation position by control panel.

![Image](image_url)

**Fig. 7-B:** The modified mechanical system.

Ozone is produces by gamma radiation inside irradiation room. It is a highly reactive of oxygen and its characteristic odor in noticeable even in concentration as low as 0.001 to 0.05 ppm by volume. The ozone concentration inside the radiation room may exceed the 0.1 ppm. There are three main elements which cause effects on ozone concentration inside the irradiation room: total volume of the irradiation room (V), radiation source activity in cruise (S) and air changes per hour (A).

The air volume inside I.R 206 design and J S 6500 design

1 - Two conveyor systems (upper & down) are sited inside the maze legs.

Each conveyor has 19 boxes (after modification)

∴ There are two conveyor (upper & down).

∴ Shelves boxes volume = 52 × 52 × 88 × 19 × 2 = 9 m³

I.R product boxes volume = 52 × 52 × 88 × 54 = 12.8 m³
Total volume of product boxes = 9 + 12.8 = 21.8 m³

2 - J.S 6500 unit (before modification)

Product box volume = 45 × 45 × 90 = 0.18 m³

I.R product boxes volume = 0.18 × 60 = 10.9 m³

Maze shelves boxes volume = 0.0 (there is 1 carrier only)

∴ The space of interior volume of J.S 6500 > the space of interior volume of I.R 206

∴ Ozone concentration inside I.R 206 > Ozone concentration inside J.S 6500 (During same radiation source activity in curies, same air average of air changes per hour) Table (4A, B).

Table (4 A): The effects of different elements on Ozone concentration:

<table>
<thead>
<tr>
<th>Volume ft³</th>
<th>Source Activity in curies</th>
<th>Air change per hour (A) and ozone concentration ppm (C)</th>
<th>Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>6500</td>
<td>1 × 10⁶</td>
<td>20 1.00 40 1.10 60 0.8</td>
<td>With not product volume</td>
</tr>
<tr>
<td>7098</td>
<td>1 × 10⁶</td>
<td>20 1.1 40 1.5 60 0.4</td>
<td>With 1 carrier only</td>
</tr>
<tr>
<td>6900</td>
<td>1 × 10⁶</td>
<td>20 1.2 40 1.7 60 1.02</td>
<td>With conveyor</td>
</tr>
</tbody>
</table>

Table (4 B): The effects of different elements on Ozone concentration:

<table>
<thead>
<tr>
<th>Volume ft³</th>
<th>Source Activity in curies</th>
<th>Air change per hour (A) and ozone concentration ppm (C)</th>
<th>Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>6500</td>
<td>1.5 × 10⁶</td>
<td>20 1.8 40 1.6 60 1.4</td>
<td>With not product volume</td>
</tr>
<tr>
<td>7098</td>
<td>1.5 × 10⁶</td>
<td>20 1.85 40 1.64 60 1.4</td>
<td>With 1 carrier only</td>
</tr>
<tr>
<td>6900</td>
<td>1.5 × 10⁶</td>
<td>20 1.9 40 1.7 60 1.5</td>
<td>With conveyor</td>
</tr>
</tbody>
</table>

The work shows: is a necessity need to design the second mechanical system that allows pushing a calculated air volume from outside irradiation room to inside it. That increases the average of air volume changing each hour which leads for decreasing ozone concentration inside irradiation room. That requires the ventilation system capable of providing minimum changing equal 20 air change / hour during normal operation. Fan motor power is raised to exhaust bigger air change / hour more than before modification. Because the volume of I.R 206 irradiation room became fewer than volume of J.S6500 irradiation room after adding 38 product boxes on the two shelves of roller bed conveyor system inside the maze of the modified facility after last modification.
CONCLUSION AND RECOMMENDATIONS:

* There is a need to modify the mechanical system of conveyor system that will allow trancing away the four product shelves or the four parts of them which face the two sides of source rack far away the two sides of the radiation source racks and shrouds. That leads to radiation source assembly to fall down to its safe shielded position inside the storage pool.

* There is a need to design new second mechanical system to push calculated air volume from outside to inside irradiation room to increase the average of air volume changing / hour that leads to decrease ozone concentration during irradiation processing by suitable motor fan.

The motor fan must be operate when radiation source is up and down to reduce ozone concentration after lowering radiation source down inside storage pool.

Ozone is producing during irradiation will not escape out of the maze outside irradiation facility.

The following recommendations for future research are given:

1- Determining the characteristic for design the moved parts of the mechanical conveyor system to increase radiation safety standards inside the space of irradiation facility.

2- The bad effect of firing which are caused by the stuck of radiation source rack inside irradiation facility, and their bad effects on the facility components.

3- The effect of fire accidents on concrete shielding of Co\(^{60}\) irradiation facilities.

REFERENCES:


Sources, VIENNA.
5- World list industrial gamma irradiators, AECL. Industrial Irradiation Division 1986.
12- World list industrial gamma irradiators (1986): AECL. Industrial Irradiation Division.
تصميم مقترح لنظام الميكانيكي الموحدة الصناعية باستخدام الكوبالت المشع.

عفيفي بلال كشك، بسام وصفي أبو شوشتة

قسم الهندسة الإشعاعية، المركز القومي لبحث وتكنولوجيا الإشعاع هيئة الطاقة الذرية - القاهرة - مصر.

* الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

المعالجة الإشعاعية بوحدات التشعيب الجامعي الصناعي باستخدام عنصر الكوبالت المشع (الملحقين المنير) قد حققت نجاحات كثيرة. وقد سجلت نتائج إيجابية من خلال محادثات كفاءة التشغيل لتلك المعالجة وذلك بعد إجراء تعديلات جديدة لمكنونات النظام الميكانيكي للوحدات الإشعاعية.

وقد سجلت بعض الحوادث والتتابع السلبية بعد أجراء هذه التعديلات مثل التناقص المصدر المشع نتيجة دفعة بصناديق الإنتاج بواسطة الدوافع الميكانيكية حيث أدت إلى عدم نزول المصدر المشع إلى وضع التدفق الأم ذا تلقى التنشيط. وسجل أيضا زيادة تركيزات غاز الأوزون داخل غرفة التشعيب عن المستويات الدولية نتيجة زيادة قوة المصدر المشع ونقص حجم الهواء داخل غرفة التشعيب.

و يتضح من نتائج البحث ضرورة تصميم أنظمة ميكانيكية يسمح أحدثها بنقل الأرفف المحملة بالصناعات المعطوبة بعيدا عن كلا من لوحي الحماية للصحراء المشع والمصدر المشع ذاته. ويسمح الآخر بنقل حجم محصور من الهواء إلى داخل غرفة التشعيب بهدف زيادة معدل تغير حجم الهواء/ساعة داخل غرفة التشعيب لخفض تركيزات غاز الأوزون.