ENGINEERING ASSESSMENT OF GHANA'S GAMMA IRRADIATION FACILITY

WATH Technical Report No. 16

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This publication was produced for review by the United States Agency for International Development. It was prepared by Dr. Rocco Basson, consultant to the West Africa Trade Hub.

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In October 2005, the West Africa Trade Hub (under the auspices of the USAID/West Africa Regional Program) released the *Irradiation Quarantine: Export Development Feasibility Study* conducted by Michelle Marcotte, Dr. Al-Hassan and Kofi Humado. Subsequently, Hepro Cape was commissioned to do an engineering assessment of the gamma irradiation facility on the campus of the Ghana Atomic Energy Commission, as described in Purchase Order 732-01 Hepro, by Carana Corporation.

The mission to Ghana was led by Dr. Rocco Basson, Founder and Director of Hepro Cape, assisted by Johann van Rooyen of iThemba Laboratories.

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society of Testing Materials
EU	European Union
FDA	Food and Drug Administration (of the U.S. Government)
FY	fiscal year
GAEC	Ghana Atomic Energy Commission
GIF	Gamma Irradiation Facility
IAEA	International Atomic Energy Agency
kCi	1000 Curies (Ci)
kg	kilogram (1000 grams)
kGy	1000 Grays (Gy)
lbs	pounds (weight)
MT	metric tonnes (1,000 kg or 2,200 lbs)
NGO	non-governmental organization
SOP	standard operating procedure(s)
SPS	sanitary and phytosanitary measures
U.S.	United States of America
USDA	United States Department of Agriculture
USDA APHIS	USDA Animal and Plant Health Inspection Service
USDA ARS	USDA Agriculture Research Service
UV	ultra-violet radiation
WARP	West African Regional Program of USAID
WATH	West Africa Trade Hub (of WARP/USAID)

1. BACKGROUND

The following summary is excerpted from the *Irradiation Quarantine: Export Development Feasibility Study*, conducted by Michelle Marcotte for the West Africa Trade Hub.

> The West Africa Trade Hub, a project of USAID's West Africa Regional Program, funded this study to explore the scientific, legal, commercial and institutional merits of the commercial application of irradiation as a quarantine treatment to facilitate exports from Ghana and other West African countries to the U.S.
>
> Scoped as a broad feasibility study, the project was envisioned as one that would assess current agricultural production, storage, market logistics and the economics of processing, including current and projected (with irradiation) costs and profitability. At the same time, the project was to assess regulatory, scientific and other aspects related to continued development of food irradiation. The project tasked two consultants, each working about 24 days.
>
> Key accomplishments include an improved knowledge of U.S. quarantine regulatory requirements and the remaining hurdles to be accomplished in light of the regulatory situation in Ghana, research and training needs, discussion about refurbishing current equipment and the possible location of new irradiation equipment. Additionally, through interviews with agri-food business, USAID organizations, and locally gathered data, some analysis of current and future likely commodities for irradiation was done. Suggestions for revising the Ghana Standard for Food irradiation were made. The project manager identified several agri-food business contacts who may be eventual clients or owners of irradiators. USDA APHIS (Animal and Plant Health Inspection Service), the International Atomic Energy Agency and members of the radiation processing and equipment supply industry were informed about the project and its findings and were asked to assist in moving Ghana and West Africa forward in food irradiation.
>
> On the other hand, it was more difficult to reliably determine costs of irradiation quarantine treatment here in Ghana. Our initial results show irradiation costs less than fumigation based on current yam methyl bromide fumigation costs. We hope that improved information will come to light in the report review process that will allow us to update these figures.
>
> This report outlines the next steps towards commercial irradiation quarantine treatment. The authors hope that with the information gathered in this project, and assuming the next steps can be accomplished, then potential equipment buyers and sellers can work out the costs and economic advantages.
>
> By virtue of its long history in food irradiation research, and considering its political stability, improving economic picture, and current export success, Ghana is well positioned to be the West African leader in the use of irradiation as a quarantine treatment. Since the U.S. has recently also made a very considerable advance in its regulations for the approval of irradiation as a quarantine treatment, it truly seems that this project has a good chance of eventual success.

2. THE GIF FACILITY

The Gamma Irradiation Facility of the National Nuclear Research Institute is a category 1V, wet-storage irradiator initially without automatic product loading and unloading mechanism.

It is intended to be used for the sterilization of medical and pharmaceutical products as well as treatment of agricultural produce. Research in the area of radiation modification of polymer and other materials will also be conducted.

The initial cylindrical source loading of 50,000Ci of Co – 60 (maximum capacity = 500,000Ci) is intended for pilot scale studies to confirm and establish irradiation parameters for the different applications of irradiation of the facility. Adequate provisions have been made for future upgrading of the facility to an industrial scale multipurpose system. The provisions include a second maze intended for the automatic feed or conveyor system, changing over from the circular source arrangement to the plaque source for increased efficiency of plant operation.

The facility is under the management of the Gamma Irradiation Center of the National Nuclear Research Institute. Four of the operating staff, forming the nucleus of the center, have received training relevant to their specific duties in the plant operation. It is expected that such high level personnel will continue to be trained and re-trained for the purposes of ensuring efficiency in safe operations.

2.1 General description of the facility

The layout of the facility is shown in Drawing 1, indicating the irradiation chamber, the control room, the electrical room and the deionizer room included directly in the plant operations. The dosimetry and technological laboratories and the plant manager's office are also indicated.

The maximum loading capacity of the facility is 18.5PBq (500kCi) but the initial loading, intended for pilot scale studies, is 1.85PBq (50kCi). The total activity at any time will be distributed among 20 torpedoes arranged in a circle of diameter 280mm. At the irradiation position the center of symmetry of the sources is 80cm from the floor of the irradiation chamber, allowing product boxes of dimensions 40 x 60 x 75 cm as well as aluminium containers with dimensions of 80 x 60 x 130 cm, carrying various products to be irradiated. The size of the room and the configuration of the sources allow a dose rate range between 1 Gy/h and 40 kGy/h. Turntables and other material handling devices will be used where possible to ensure dose homogeneity.

The radiation sources are stored in a water pool of dimensions 2 x 3 x 5.7m. The inner lining of the water pool is made of stainless steel type KO37. A deionizer system is in place to ensure ion-free water in the pool, thus the possibility of corrosion is further reduced.

The operation of the irradiator may be fully automatic via computer program, or manual by operating a control console. The loading and unloading of goods or products will, however, be done manually until the facility is upgraded to an industrial one.

2.2 Technical description of the facility

<u>Radiation Sources</u> (Figure 1)
The SLL-02 type Co-60 gamma irradiation facility houses 20 torpedoes, each of which is loaded with CoS-43 HH type Hungarian made sources of diameter 11mm and height 451mm. The sources are brought up to the irradiation position by a cage in which the sources are arranged in a pitch-circle of 280mm diameter.

All the torpedoes are brought up from the storage position during irradiation. A hoist mechanism lifts the cage from the storage position to the irradiation position. The positions of the torpedoes, either in the storage or irradiation positions, are indicated on the control console by means of LEDs. At the irradiating position, the horizontal plane of symmetry of the sources is 80cm from the floor of the irradiation chamber.

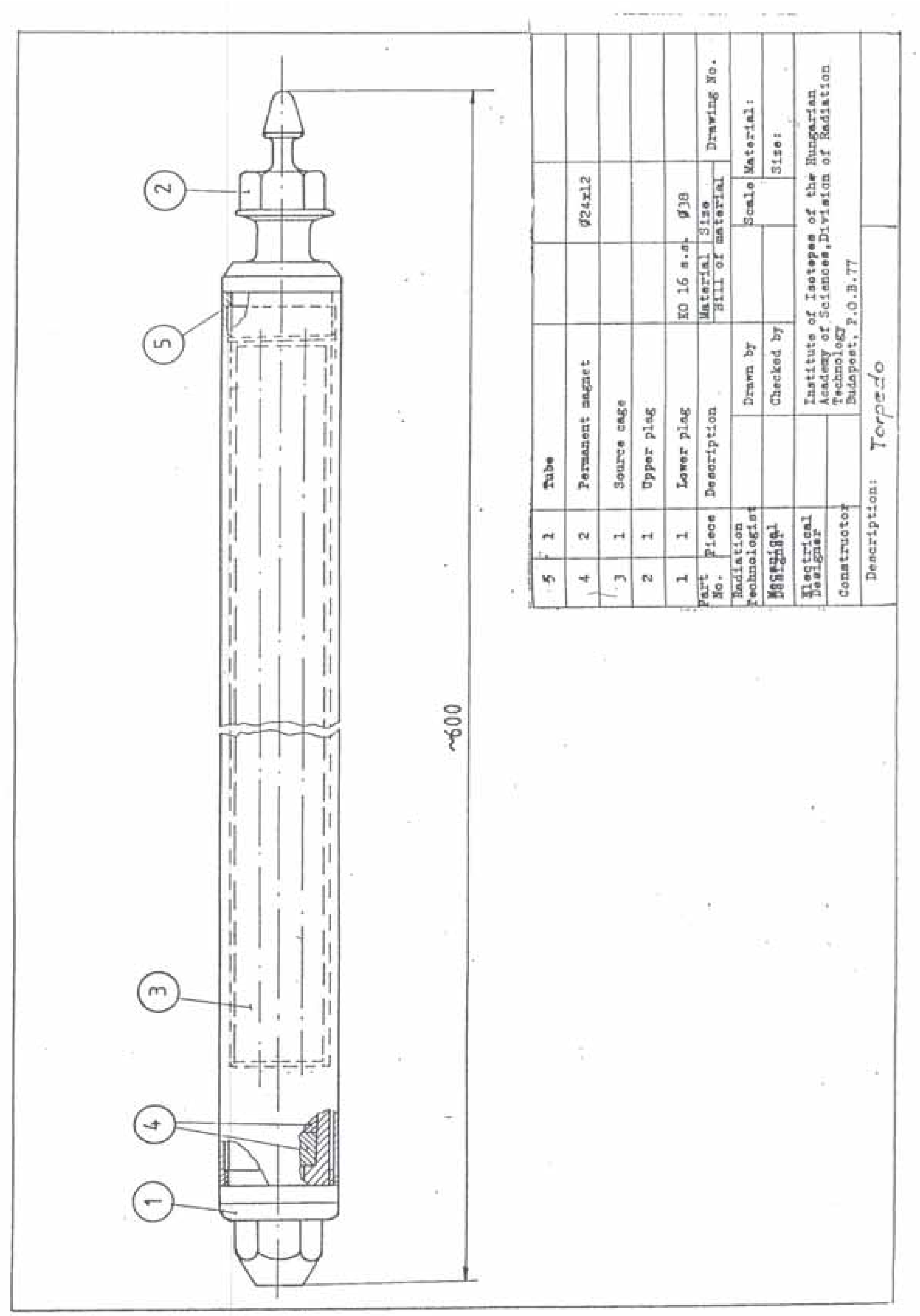
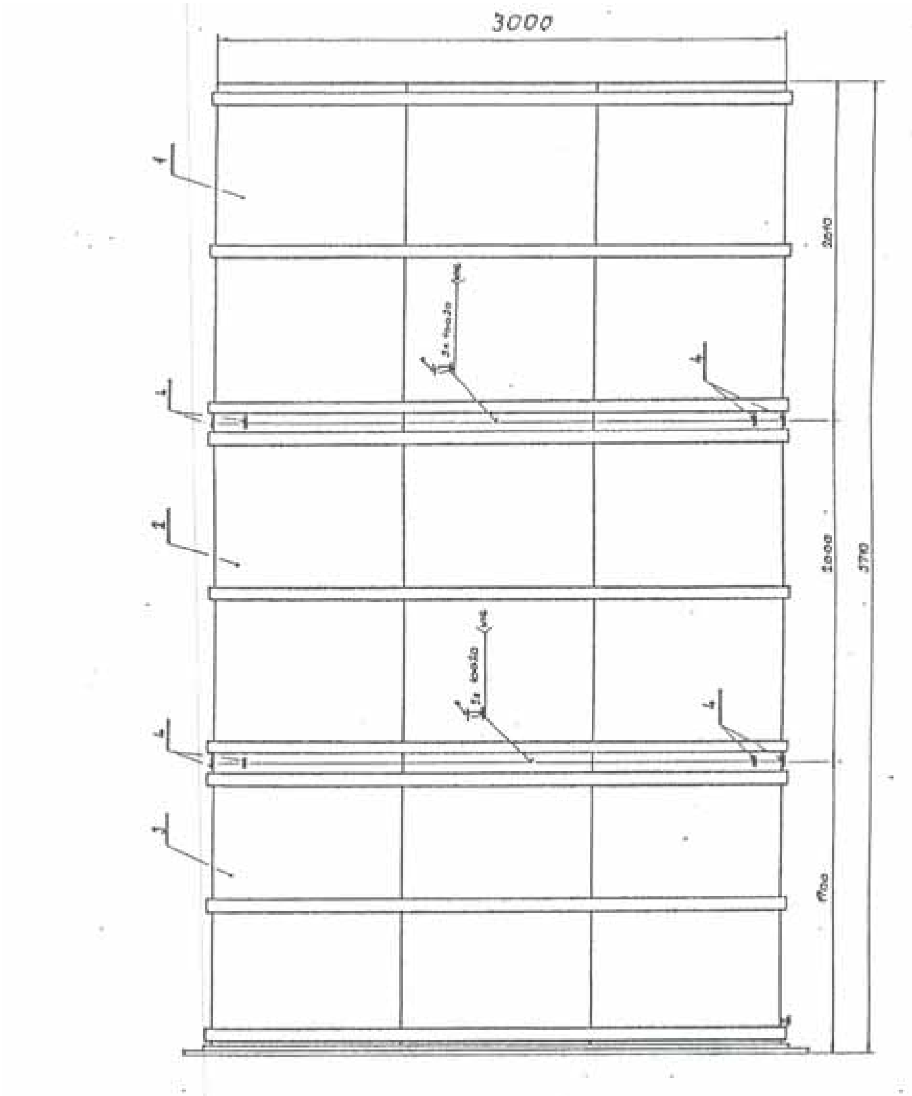


Figure 1. Torpedo

Water Pool (Figure 2)
The size of the water pool is 2 x 3 x 5.7m, and the material of the wall and cover plates is stainless steel type KO37. The arrangement of the sources allows 4.2m of water layer to serve as a biological shield between personnel in the irradiation chamber and the sources at the work storage position. During irradiation the whole water pool is covered with stainless steel plates.

The pool water is sent through an exit pipe to the deionizer for purification and when the level falls the deionizer refills by deionizing-pipe borne water connected to it. A detector attached to the deionizer also assesses the level of contamination of the pool water during the purification procedures. Another meter attached to the deionizer also measures the conductivity of the water in the pool during purification.

The pool deionizer and refiller system does not operate continuously but must be connected and operated manually during the weekly maintenance checks.



Part No.	Piece	Description
4	1	Lower unit
3	1	Upper unit
2	1	Central unit
1	16	Dowel pin

Figure 2. Water pool

Source Cage (Figure 3)
The ring-shaped source cage carries the torpedoes from their resting position to the irradiation position for the irradiation processes and back after irradiation. The hoist mechanism is mounted on top of the concrete roof of the irradiation chamber with the hoist cable connected to the source cage, and is responsible for the source cage up-and-down movements.

The source cage mainly consists of a central tube of diameter 220mm, thickness 1.5mm and length 708mm, onto which is welded a cylindrical collar of thickness (50mm) and which has holes of diameter 40mm arranged in a circle of diameter 280mm. To ensure stability of sources during movements and at the irradiation position, another cylindrical plate of thickness 5mm and with holes coinciding with those of the collar is welded onto the central tube at a distance of 208mm from the top.

The materials for the construction of the various parts are stainless steel types KO16, KO33 and KO34.

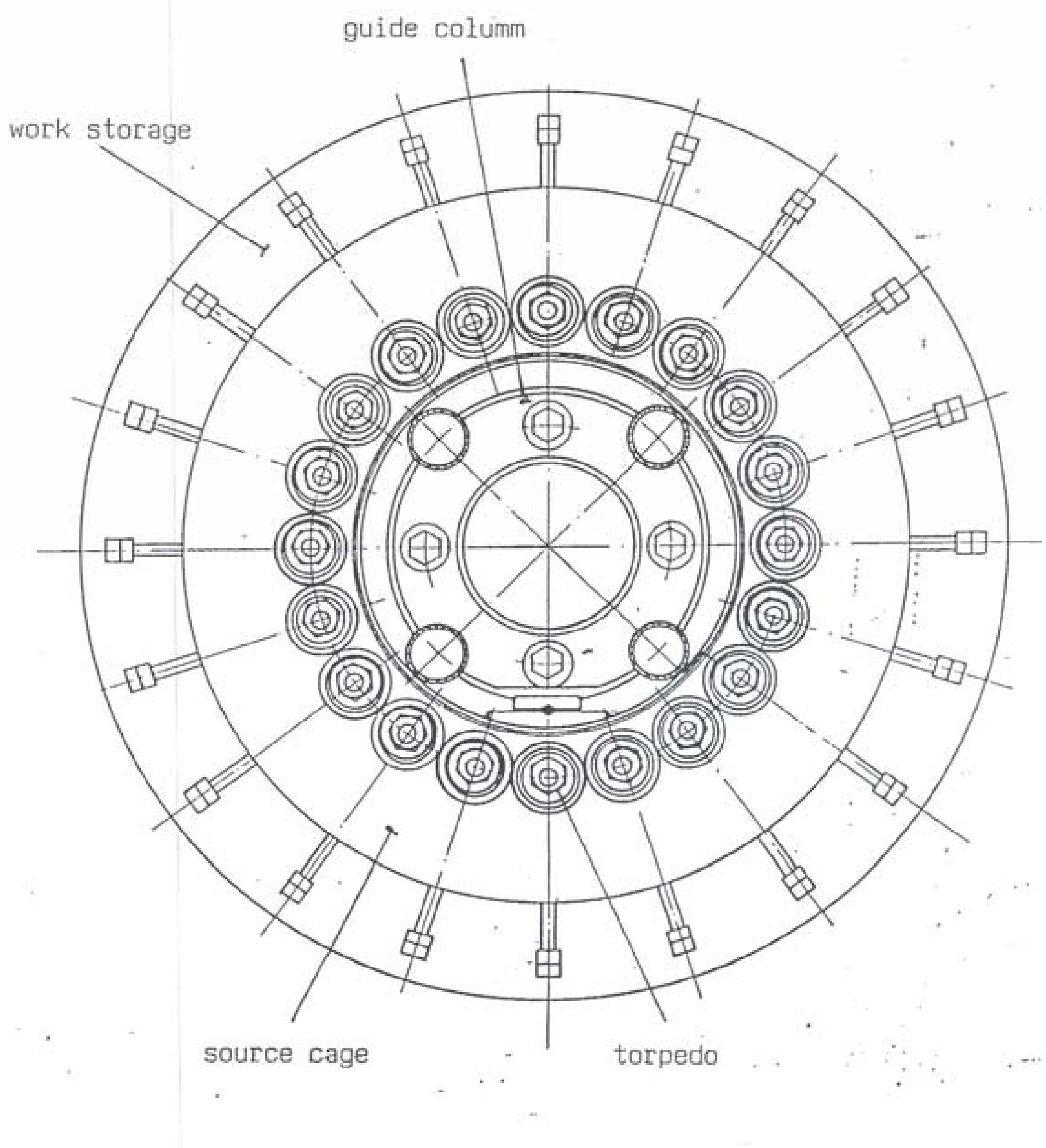


Figure 3. Work storage with torpedoes

Cage Guide Column (Figure 4)
The cage guide consists of the four (4) guiding tubes, each of diameter 40mm and thickness 3mm, welded onto the circumference of a bigger central tube of diameter 108 and thickness 4mm. The whole column is in three parts, the bottom, middle and the upper sections, joined together by means of bolts and nuts and the flanges at the joints. The bottom section is placed on the storage stand while the upper part is welded onto the cylinder surrounding the inner irradiation field.

Similarly, the stainless steel types KO16, KO33 and KO34 were used for the fabrication of the cage guide column.

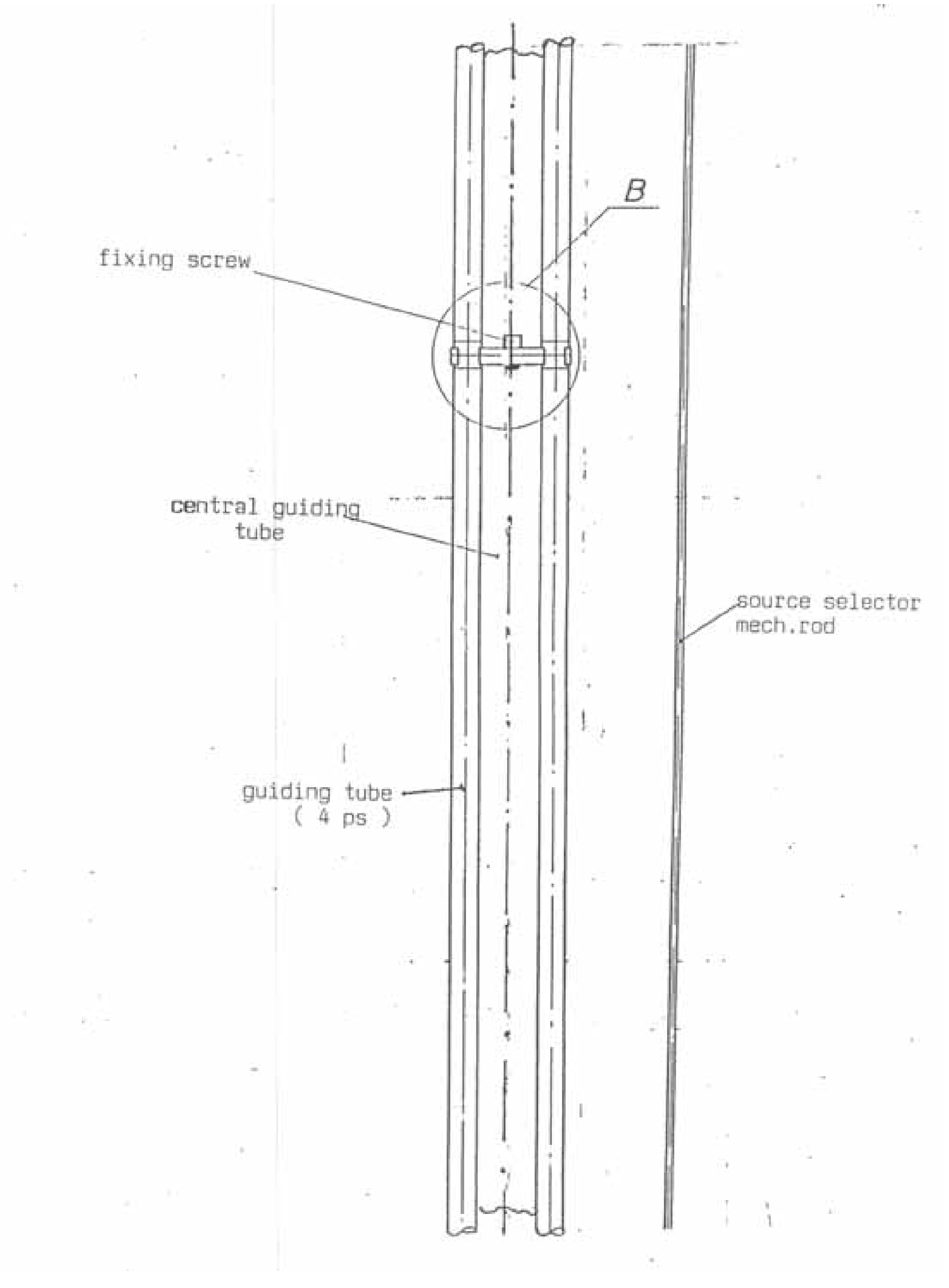


Figure 4. Cage guide column

Hoist Mechanism (Figure 5)
The hoist mechanism is located on the roof of the irradiation chamber and connected to the source cage by means of two stainless steel ropes of diameter 6mm each. By specification a rope of diameter 8mm can conveniently be used with the rope guide tube.

The lifting motor is connected to the cable-drum onto which the upper end of the stainless steel ropes is fixed. The motor turns the drum, which causes the rope to be wound around the drum in defined grooves cut on the drum, and thereby causes the movement of the source cage. The ropes carry permanent magnets which affect a reed-relay attached to the ends of the rope guides. The approach of the magnets to the reed-relay systems sends signals to the motor to switch it off. The cage finally stops at the irradiation position by electromagnetic brakes coupled to the hoist mechanism.

The source cage returns to the shielded or storage position at the specified time under gravity, but the speed is again checked by the electromagnetic brakes. The electrical operating signals of the safety system are connected to the circuit of the electromagnetic brake, so that unless all other conditions are satisfied, the hoist system cannot be operated.

Source Cage Shield
At the irradiation position, the source cage is physically shielded by the source cage shield. The shield is a simple cylindrical drum of length 1035mm and diameter 540mm. The upper section of the cage guide terminates in this shield. At the irradiation position, the source is sandwiched between the upper section of the cage guide and the shield. There are holes drilled in the upper section of the drum to facilitate cooling of the source pencils and for ventilation purposes to remove the products of radiolysis of the components of air.

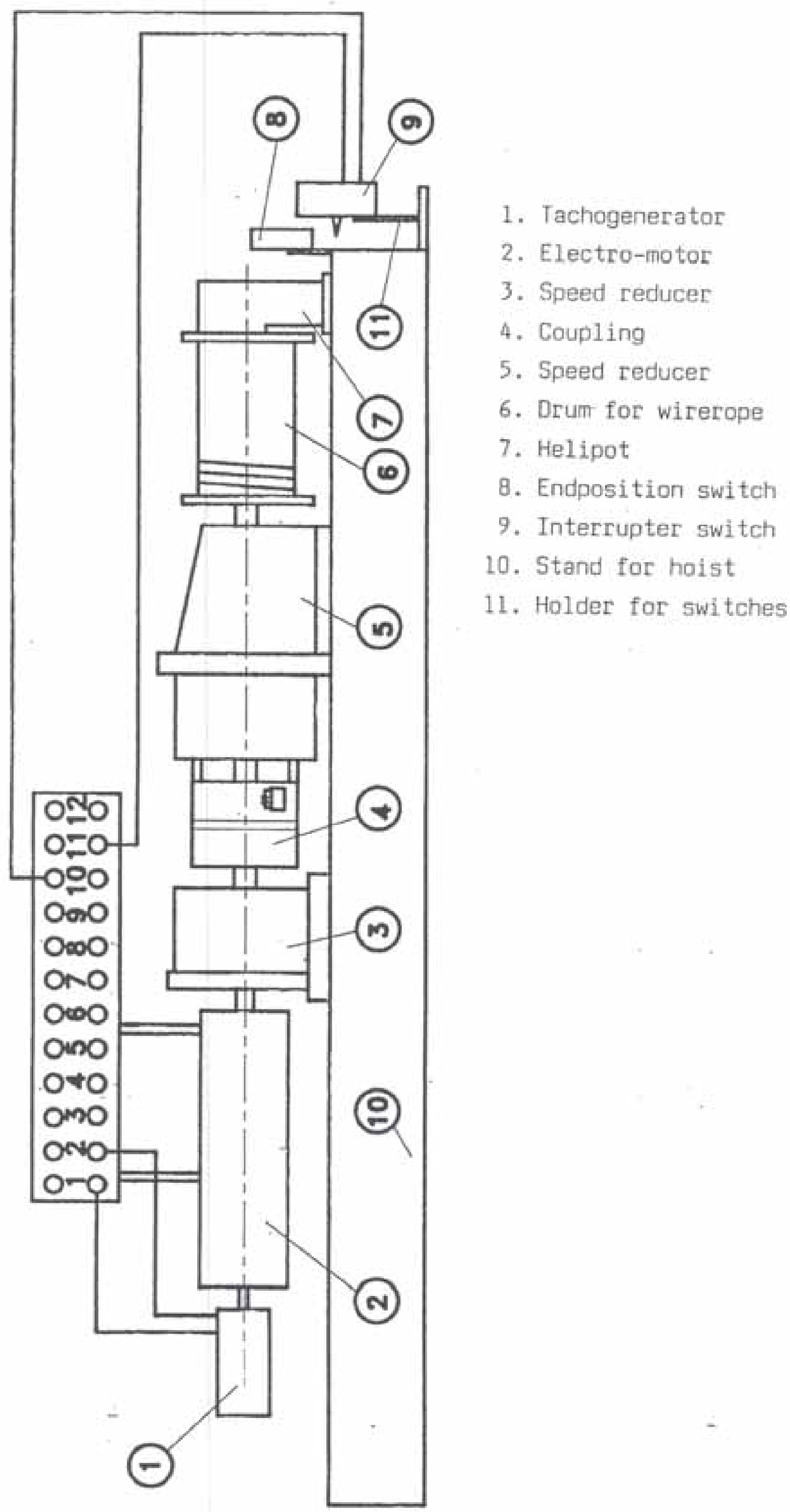


Figure 5. Hoist mechanism

3. ASSESSMENT FINDINGS

This section details specific replies to items in Terms of Reference (see Annex 1 for complete terms).

Building structural assessment

1. The slated maximum leading capacity of the facility is 500kCi. At present it is 7kCi and is proposed to be upgraded to 200kCi of Cobalt – 60. At this loading a person standing next to the bioshield walls outside the building can be exposed to as high as 8 micro Sieverts / hour, 15 times higher than natural background. However if a mesh fence with warning signs 2 metres from the outside wall is erected, the occupancy factor becomes zero and there is no radiation hazard to workers or general public.

2. There is a unique magnetized interlock key. To raise the source this key must be inserted and turned in the console in the control room. This is also the only key into the irradiation chamber and is attached to a hand-held radiation monitor which must be taken along for every entry to the chamber. According to standard operating procedures the monitor is checked at the maze door against a check-source mounted on the wall.

Generally speaking, installed fixed, hand-held and electronic personal detectors are either outdated or unserviceable and require upgrading or replacement. Costs are estimated as follows:

Equipment	=	U.S. $ 20,000
Training	=	U.S. $ 3,500

3. Standard operating procedures need to be reviewed and improved. These include personnel and product entry protocols; modifications to control console to be done professionally, documented and approved by the Radiation Protection Institute.

4. The facility is secured by adequate steel doors, a high-security fence and a permanent security guard. No further measures are envisioned.

5. Source-related elements:

- The pool is well constructed and in good condition.
- The cover plates ensure that entry by dust and dirt is minimized and though an underwater light was not available, the water appeared to be very clean.
- The de-ioniser is working well.
- The design of the cylindrical source is unusual but is certainly usable given the right product handling design. It contains 20 “torpedoes” which have 4 compartments, each of which can house standard Nordion “pencils” – at present each torpedo contains only one pencil. Handling tools to load more pencils are available and there is a crawl beam in the ceiling which can be used to lower the transport container into the pool.
- The shroud is adequate and the hoist mechanism works smoothly and safely. An inexpensive cover over the hoist to keep out dust is recommended.
- No major upgrading is recommended, even at the maximum loading of 500Kci.

6. Control Panel

Although the control panel is suitable for the safe operation of the irradiator, a large part of it is redundant and not used. If the irradiator is refurbished according to our proposal, it would be better to replace the control panel altogether. Costs associated with this are:

The cost of replacement	=	U.S. $ 120,000
The cost of training	=	U.S. $ 10,000

7-8. Dosimetry Laboratory

The dosimetry lab is very well equipped and the scientist in charge is very competent. Record keeping and filing need to be improved but this training is not major and could be combined with the training related to section 6.

9-11. Warehouse

Although the current warehouse is small, it can be divided by a solid wall as shown in Diagram 1 (see Annex 2).

The treated product side will be covered by an insect-proof ceiling and accessed by containers from a new loading platform equipped with suitable insect-proof seals and padding.

The remainder of the warehouse will be open to the exterior but insect-proof screens will be provided at the entrances to the labyrinths, which are both functional.

This proposal is for the first phase of the refurbishment program and the divided warehouse will not be able to handle more than one 12m container load per day. Nevertheless this is a realistic amount for trial shipments in the early stages of the program.

Once the process has been demonstrated to exporters and the product acceptance in the U.S. has been established, the warehouse can be expanded as required.

The cost of the warehouse modifications must be assessed locally, but preliminary enquiries indicate an amount of less than U.S. $10,000.

12-13. Facilities Assessment

In addition to existing management and technical staff, four to six manual laborers will be required to handle the throughput envisioned. Existing office space is totally inadequate and it is proposed that a new floor be constructed above the existing office, laboratory and toilet area.

The upstairs addition could accommodate an administrative office (manager, secretary, and bookkeeper), an office for the technicians, and a recreational area for the laborers.

The cost of the additions must be assessed locally, but preliminary enquiries indicate an amount of less than U.S. $5000. Likewise the cost of office equipment must be assessed locally.

14. Processing Parameters (Refurbishment Proposal)

The following requirements have been considered:
- Irradiation times must be reduced significantly
- Manual product handling must be eliminated
- USDA APHIS quarantine rates must be met
- Existing equipment must be retained as far as possible
- Simplicity of operation must be a priority

It is our opinion that a new facility to meet these requirements is not necessary – in fact it would be a white elephant for many years. A successful radiation processing business does not take off immediately and has a long induction period. During this time it runs at a loss.

On the other hand, a small refurbished facility has a small income earning potential (medical products) almost immediately and can grow slowly while demonstrating the technology on a semi-commercial scale.

We therefore would like to propose the following:

a) Increase the source strength to approximately 200kCi by loading one standard C188 pencil in each of the torpedoes.
b) Install four turntables in the chamber which will allow product to surround the source.
c) Move four pallets (dimensions 1m long x 0.8m wide x 1.2m high) through the personnel maze, into the chamber using pallet jacks manually and place them on the four turntables.
d) Activate the safety mechanisms, lock the doors, raise the source and initiate the automatic pallet rotation mechanism (see Diagrams 2 & 3 in Annex 2).
e) At the end of the irradiation cycle the source will automatically return to its safe storage position and the doors can be opened.
f) Product pallets are removed through the goods maze.

Apart from the fact that the GAEC source is round and not square the system is very similar to the BP1 facility in Cape Town which has been operating successfully for 20 years. It is robust, reliable, simple and inexpensive to run and is ideal for a developing country (see brochure in Annex 3).

This proposal, combined with the proposal for an insect-proof finished product section of the warehouse, will satisfy USDA APHIS quarantine regulations.

In order to determine the processing parameters for agricultural produce with a packed density of 0.35gm/cm^3 we have taken the measured throughput of BP1 and assumed, conservatively, that GAEC – GIF will be 50% as efficient. This results in the following figures:

Source Strength :	200kCi
Minimum Dose :	400Gy
Processing time :	96min
Batch change time:	14min
Total time:	110min
Batch mass:	1.4ton (4 pallets)
Processing Rate:	0.76t / hr
	18t / day (1 container)

15. Capital and Processing Costs

<u>Equipment</u>

Number	Items	U.S. $ (000's)
1	Design fees	20
4	Turntables	85
1	Pneumatic assembly	25
1	Control / Safety panel	120
2	Hand monitors	20
4	Pallet jacks	20
1	Transport to Accra	30

1	Installation (30d)	20
1	Contingencies	20
	TOTAL	**360**
	Building changes	15
	Cobalt-60: 200kCi	400
	OVERALL TOTAL	**U.S. $775**

<u>Operating costs</u> (see Table 3, Marcotte et al.)

Salaries, etc.	62
Co – 60 replenishment	50
Maintenance	30
Depreciation – equipment	36
Interest on loan (10%) for 10 years	16
TOTAL	**U.S. $194**

Total operating cost including 20% profit = U.S. $233

In 14, the maximum processing rate = 18t / day
= 6300 ton / year

Treatment cost = U.S. $ 0.037 / ton

16. Quarantine Treatment (this has been dealt with in previous sections.)

17. Cobalt – 60 (Not applicable)

18. Training (dealt with previously)

19. Facility Uses

The facility can be used for:

- Trial shipments to the U.S. to demonstrate efficacy as a quarantine measure
- Decontamination of herbs & spices
- Extension of shelf life of locally marketed produce
- Sterilization of disposable medical goods

20. Cost of New Facility

	U.S.$ (000s)
BP1 Complete Equipment	1,500
Bioshield	300
Building	500
Cobalt – 60: 200kCi	400
TOTAL	**U.S. $2,700**

<u>Conclusion</u>
The existing GAEC – GIF can be upgraded into a medium-sized facility at a cost of less than U.S. $ 1 million; we conclude that a new irradiator is not required at this stage.

ANNEX 1. TERMS OF REFERENCE

This document describes the terms of work for an engineering assessment of the GAEC irradiator, and an assessment of whether the refurbished irradiator could meet Ghana's irradiation requirements in the near future or whether a new irradiator is necessary. When conducting this study, the contractor should use, cite and reference as appropriate ASTM and other international standards, U.S. regulations and standards for facilities containing cobalt-60.

Elements of the engineering assessment:

Building structural assessment

1. Examine the building shield to determine if it is sound enough to safely contain its rated capacity of 50,000 curies. If not, determine its safe cobalt-60 loading capacity.

2. Examine door interlocks and all other personnel and product entry safety systems and equipment to determine if they comply with current standards.

3. Review personnel and product entry protocols and make suggestions to update if necessary.

4. Review and advise on site security issues or protocols needed to meet current requirements to safeguard cobalt-60.

If these elements require upgrading, provide cost quote for refurbishment or replacement, and including personnel training.

Source-related elements

5. Examine the source pool, rack, shroud and hoist mechanisms and assess their safety and functionality for the future and report whether they would be sufficient for cobalt loading up to the facility's rated capacity.

If these elements require upgrading, provide cost quote for refurbishment or replacement.

Control panel

6. Examine the control panel and determine if it will be suitable and provide for the safe operation of a refurbished irradiator.

If these elements require upgrading, provide cost quote for refurbishment or replacement, and including personnel training.

Dosimetry lab

7. Examine dosimetry lab equipment and range of dosimeters available. Determine if adequate for the range of purposes outlined in the feasibility study, or if upgrading or additional equipment is required. Refer to the USDA APHIS facility checklist requirements for the dosimetry lab and dosimeters to determine if the current lab and equipment will be sufficient.

8. Make suggestions for additional personnel training if required.

If these elements require upgrading, provide cost quote for refurbishment or replacement, and including personnel training.

Warehouse

USDA APHIS regulations describe the requirements for facilities suitable for use as a quarantine irradiator. Among other things, these requirements include that pre and post irradiated product be held in completely separate warehouses and that there be no possibility that flying insects could move from untreated to treated product, or encroach from the outside to infest food.

Examine product entry and exit maze. Currently the product exit maze appears damaged or non-functional. A functional exit maze will be required to move treated product to the separate warehouse for treated product.

9. Currently, there is no separate warehouse for treated product. Assess whether it would be possible to build a new finished product warehouse on the exit side of the irradiation chamber, attached to a functional product exit maze.

10. Assess current warehouse and refrigeration equipment for suitability to meet the objectives of the irradiation feasibility study.

11. Examine and review seals and padding around loading docks in current warehouse to determine if they would provide an insect proof seal against intrusion from outside pests.

If these elements require upgrading, provide cost quote for refurbishment or replacement.

Facilities assessment
The WATH feasibility study describes the staffing that will be required at an irradiation quarantine treatment center.

12. Examine the office space, office equipment, toilets and sanitary and cleaning and other facilities available and determine if sufficient to meet the future needs for product processing, quality control and records management. If not, advise what additional offices, facilities or equipment are required.

13. Assess current lighting and power availability and reliability, and advise on upgrades if necessary.

If these elements require upgrading, provide cost quote for refurbishment or replacement.

Processing parameters
It is possible that a refurbishment may not be sufficient to bring the GAEC irradiator up to all the capabilities described in the feasibility study. Furthermore, the current entry maze is narrow and does not seem likely to allow for any automated systems.

14. For whatever refurbishment is advised or appears possible, include an assessment of the resulting processing parameters for the products likely to be irradiated.

15. Also include processing costs of likely volumes of fruits and vegetables if cobalt loading is increased to facility rated capacity. If the facility can not safely be loaded to capacity, indicate the advisable cobalt loading, and the resulting processing costs.

16. Review the warehouse size and design and product mazes, assess process work flow and capacity for the quarantine treatment of fruits and vegetables.

Cobalt 60
17. If the contractor is a supplier of cobalt-60 pencils, provide a price quote, including transportation, rental of transport containers and installation.

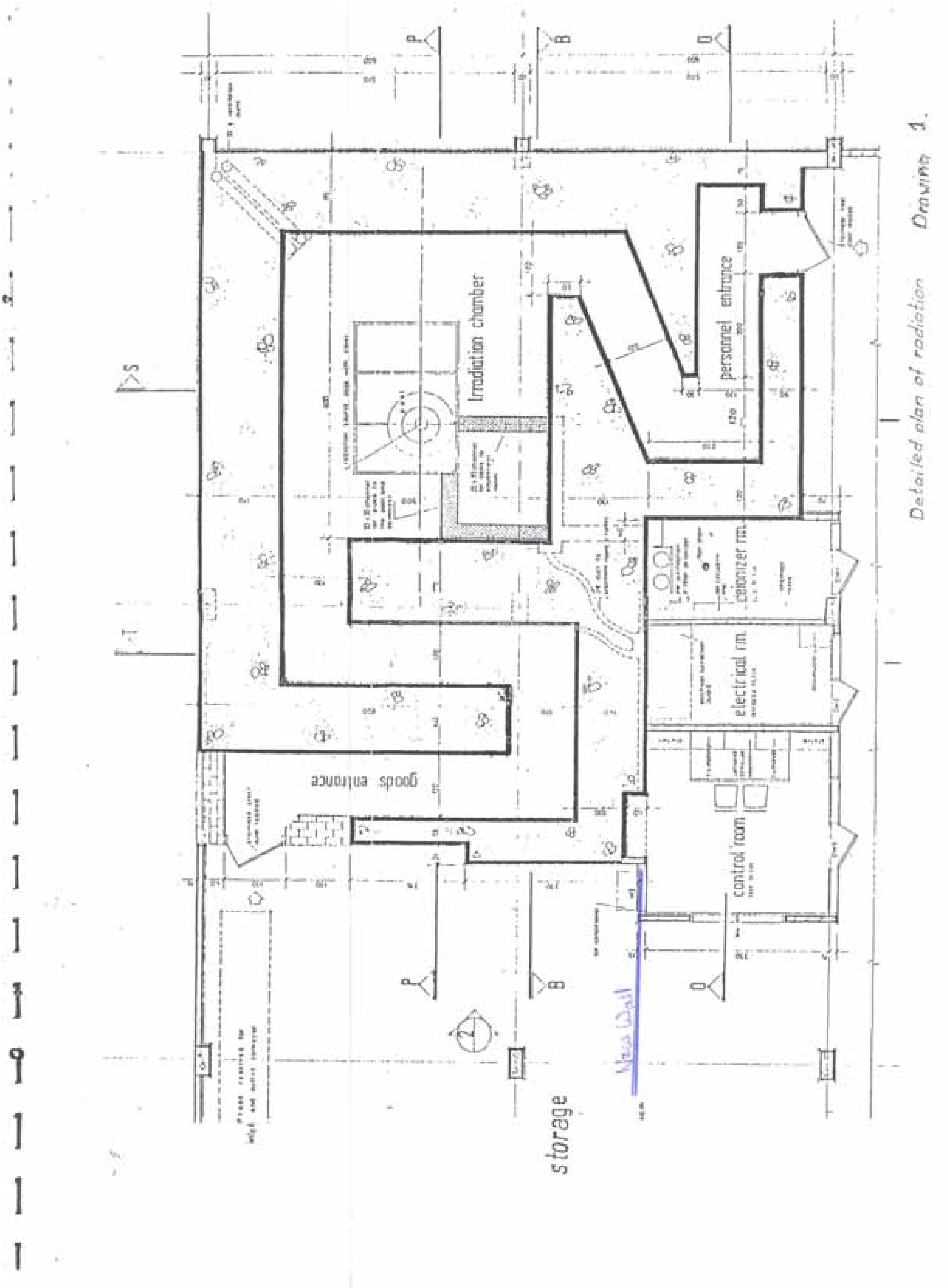
Training requirements
18. If additional training of current staff is found to be advisable, indicate course possibilities and costs.

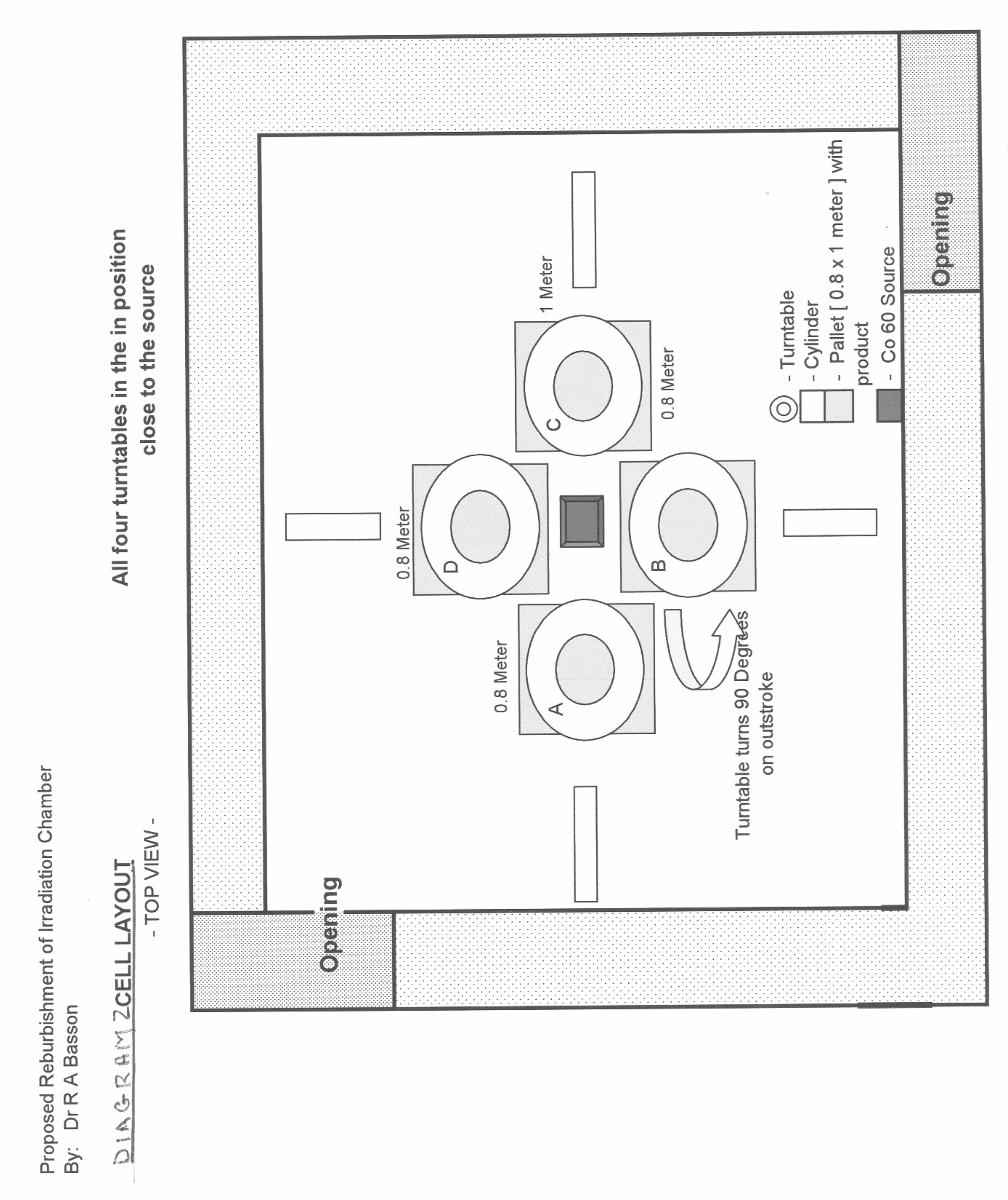
Other options

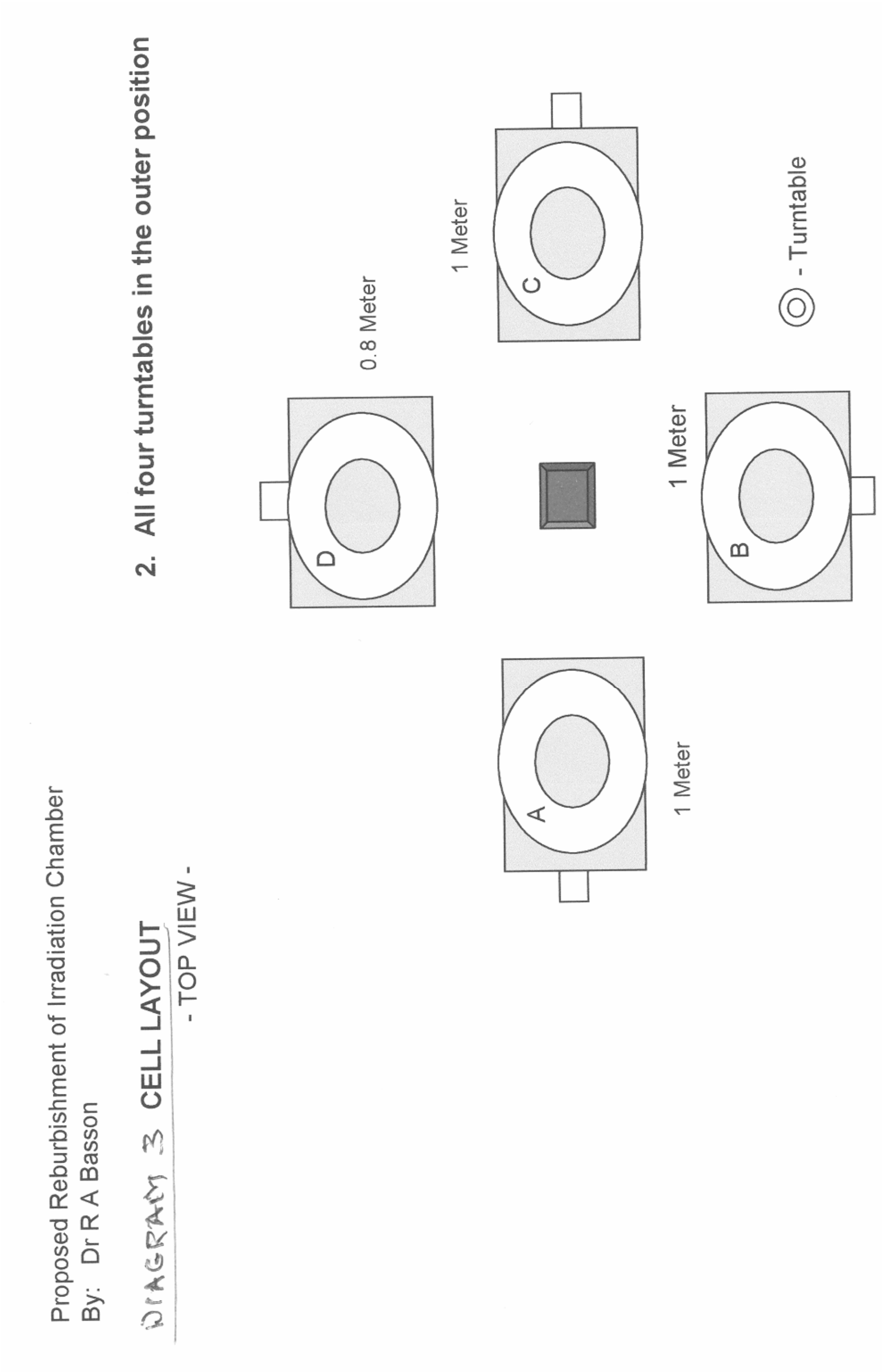
19. If it is not feasible to refurbish the GAEC irradiator to meet USDA approval for quarantine treatments, the contractor should estimate to what degree the facility can be refurbished and to what uses it could be put.

20. The contractor should also provide a quote for the price of a new facility that would meet the needed standards.

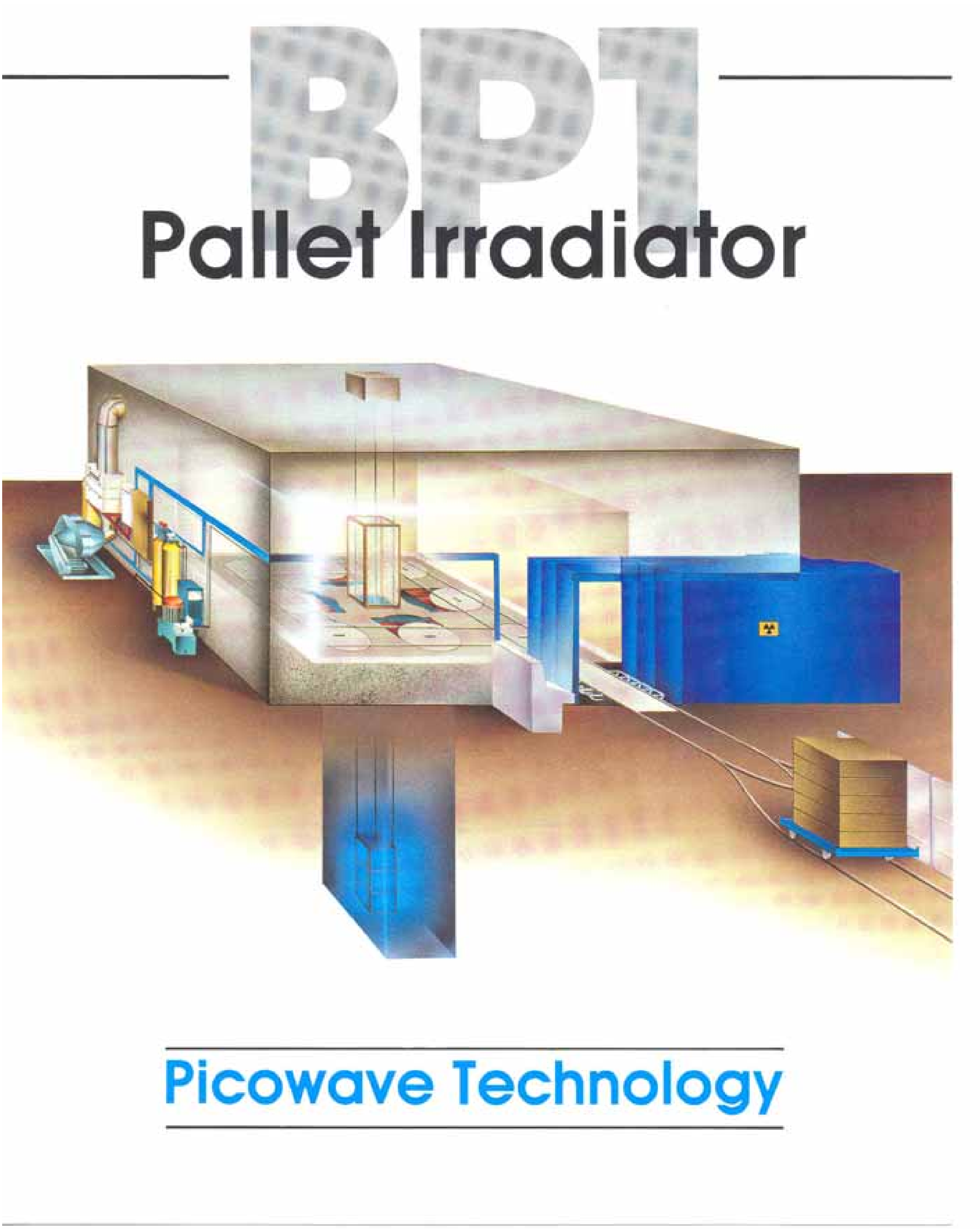
ANNEX 2. PROPOSED REFURBISHMENT DIAGRAMS




Proposed Reburbishment of Irradiation Chamber
By: Dr R A Basson
DIAGRAM 2CELL LAYOUT
- TOP VIEW -
All four turntables in the in position close to the source
Opening
Opening
1 Meter
0.8 Meter
0.8 Meter
0.8 Meter
A
B
C
D
Turntable turns 90 Degrees on outstroke
- Turntable
- Cylinder
- Pallet [0.8 x 1 meter] with product
- Co 60 Source


Proposed Reburbishment of Irradiation Chamber
By: Dr R A Basson
DIAGRAM 3 CELL LAYOUT
- TOP VIEW -
2. All four turntables in the outer position
0.8 Meter
1 Meter
1 Meter
1 Meter
A
B
C
D
- Turntable

ANNEX 3. BROCHURE FOR BP1 IRRADIATOR


BPI
Pallet Irradiator
Picowave Technology

Introduction

A pallet irradiator of exceptional simplicity has been designed and has been operating successfully for almost a year. This irradiator can be lucratively applied by developing countries with limited resources and also on site as an in-house facility.

The pallet concept has solved problems related to product handling and variation in doses, as experienced at commercial food irradiation plants employing bins as irradiation containers.

The advantages of the pallet system

One of the most prominent advantages of the BP1 pallet irradiator is that it eliminates problems related to package dimensions. An internationally standardized pallet of 1 200 mm by 1 000 mm can handle unusual containers such as drums and large bags, as easily as carboard cartons. With the pallet system, handling damage is also reduced considerably.

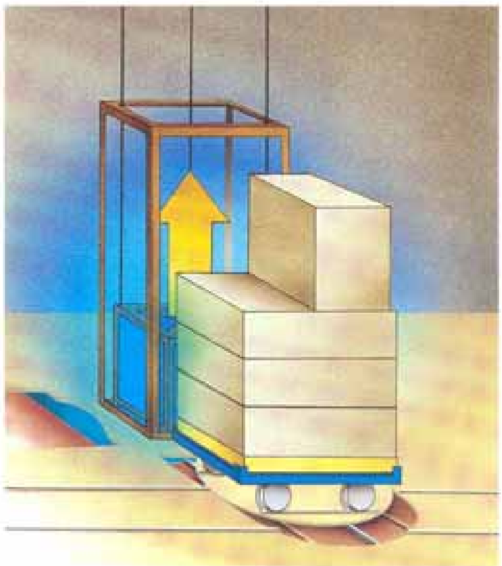
The pallet concept allows for better volume utilization. A pallet stacked 1 500 mm high has a volume of 1,8 m^3. A greater mass per batch can also be treated compared to that of conventional irradiators employing bins.

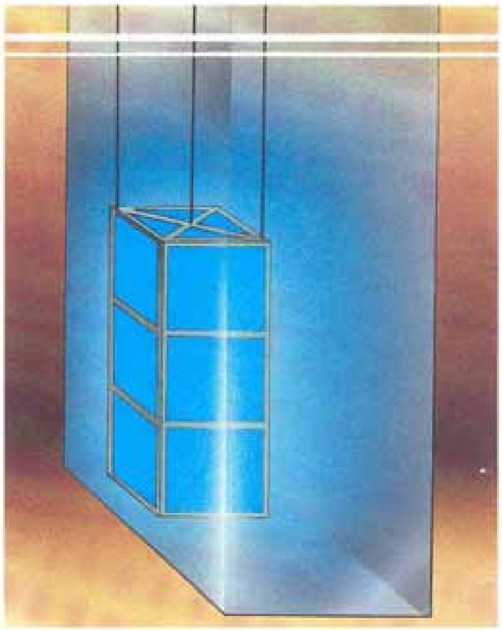
Handling time when batches are changed become a limiting factor when the average dose is low or when throughput is very large – this problem is however rarely encountered in practice.

Operation

The pallet irradiation system operates as follows:

- The produce containers are stacked onto

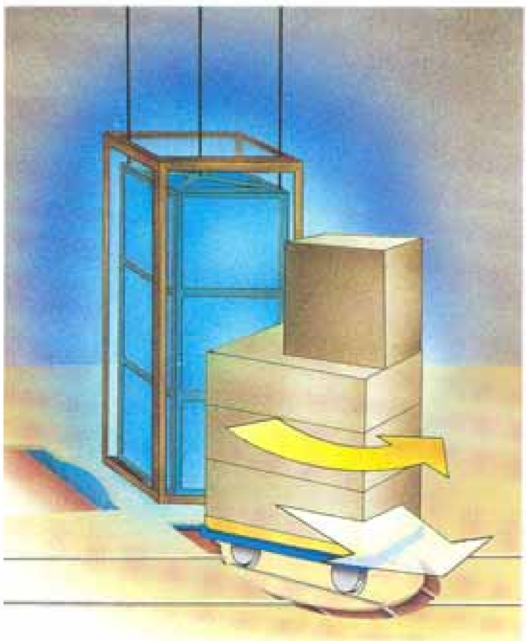


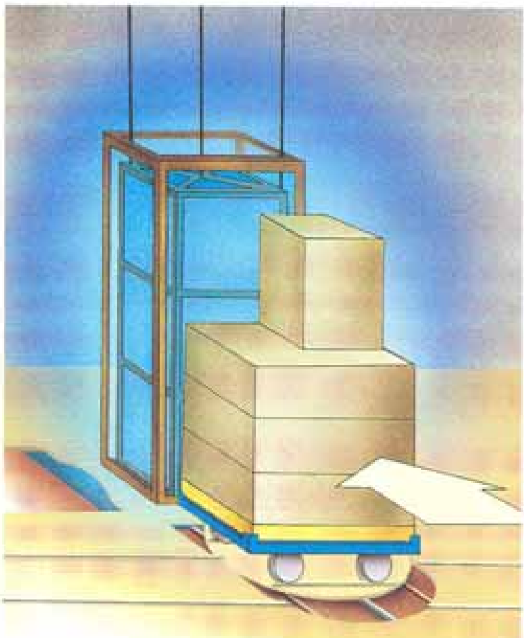


BP1 Pallet Irradiator

pallets which are then loaded onto four trolleys positioned on a rail track.

- The trolleys are pushed manually into the irradiation chamber.
- Through a system of rails and turntables, the pallets are arranged around a square protective shroud separating them from the source frame. This shroud protects the source frame, should a container fall from the pallet.
- When not in operation, the source frame is stored at the bottom of an eight metre deep stainless-steel lined pool.
- The operator inside the irradiation chamber initiates the process with a key switch.
- Staff leave the chamber.
- The operator mobilises the door with the same key used previously. The door is a concrete plug, covered with steel.
- When the door has been closed, the operator uses the key to activate the control console.
- The source rack is pneumatically raised to the operating position at the centre of the four pallet stacks, provided that the interlock procedure and equipment monitoring systems are in the safe situation.
- Once the source is raised, irradiation commences with the pallets in their fixed positions until a quarter of the total exposure time has elapsed.
- The four pallets are rotated 90 degrees by means of a pneumatic mechanism which pulls each turntable away from the source, rotates it and then pushes it back against the protective shroud.
- All four pallets turn simultaneously.
- This action takes place three more times at appropriate intervals to ensure that each side is equally exposed to the source.





The irradiation process

The source rack is a square frame carrying 12 modules on three levels. Each module can accept 25 cobalt pencils of the AECL C – 188 type. Up to 1 200 kCi is achieved through this loading.

The source rack is connected to the hoist by a stainless steel cable and two guide cables restrain lateral movement. Limit switches monitor its movement and govern its final position.

Because of the bulk of the target, the overdose ratio in a pallet irradiator will be higher than in irradiators employing smaller containers. This could be a disadvantage in certain applications. As overdose ratio is a function of density, bulky stacks could present specific problems.

Some typical values for uniformly packed stacks are:

Density (gm/cc)	Overdose ratio
0,1	1,3
0,2	1,6
0,35	2,2
0,45	2,6

In the operational plant, no problems have been experienced even at the highest densities. Should problems arise, the overdose ratio can be reduced by as much as 20% by using steel attenuators to lower hot spots or by stacking the product in a chimney on the pallet, forming a central cavity in the stack.

Features of the pallet irradiator

- The simplicity of this irradiator is its most redeeming feature.
- The operation and maintenance of the plant is straightforward, reducing costs considerably.
- Machinery is simple and therefore very cost-effective.
- A small labour component is required.
- High throughput and acceptable overdose ratios are obtained. Throughput figures vary with density and packing efficiency, but more than four tons per hour at an overdose ratio of 2,6 has been achieved for a source loading of 240 kCi at a normalized dose of 1kGy. These figures compare favourably with others quoted for pallet irradiators.
- The pallet irradiator is versatile and can be utilized to process a wide range of products and containers.

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