RADIATION TECHNOLOGY EQUIPMENT
- INDIAN SCENARIO -

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ABSTRACT:

Radiation Technology Equipment houses high intensity radioactive material in a particular configuration and is equipped with various types of systems to facilitate controlled exposure of radiation on materials under investigation to study the effect of irradiation. These equipment are designed and manufactured as per national & international standards. They are versatile, safe to work & can be easily installed in a existing building without any additional shielding. Radiation Technology Equipment developed by BRIT are ideally suited for carrying out irradiation works for research and development in fields of Medicine, Industry, Agriculture and Research. These equipment are housing Co-60 source of up to 100 kCi activity providing high / low intensity of radiation dose rates as per the users requirements.

The paper briefly deals with design, development, manufacturing and their application aspects for some of indigenously developed equipment like Gamma Chamber 5000, Gamma Chamber 1200, Blood Irradiator 2000, PANBIT (Batch type Irradiator) & ROLI-1 Radiography camera. Presently a number of such types of units are in operation at different institutions within the country and abroad and are found very useful in propagation of radiation technologies for societal benefits.

INTRODUCTION

With increasing applications of radiation and radioisotope in the field of Medicine, Industry, Agriculture and Research, there are need to have different types of radiation technology equipment which are compact, versatile and safe to use. Board of Radiation & Isotope Technology (BRIT) therefore has designed and developed indigenously certain types of radiation technology equipment for their use in laboratories and institutions for research and development purposes. These equipment are versatile, users friendly, safe to operate and conform to national and international standards.

A very stringent quality control and assurance programme is adopted during all stages of design, manufacturing, testing and commissioning to assure trouble free and reliable functioning of the units.

DEVELOPMENT OF EQUIPMENT

Radiation Technology Equipment houses high intensity radioactive material in a particular geometrical configuration and is equipped with various types of systems to facilitate controlled exposure of radiation on materials to study the effect of irradiation. A number of features have been incorporated in the design to meet the specific requirements of users. Development of radiation technology equipment, therefore, calls for the need to meet a number of necessary but often conflicting requirements not only from functional and regulatory point of views but also from manufacturing point of view. Therefore, a balance needs to be maintained while optimizing the design of the various systems of the unit to achieve high degree of performance, reliability and cost effectiveness.

DESIGN CONSIDERATIONS

The following considerations are to be met during design

(a) Functional

(b) Regulatory and safety
(c) Manufacturing
(d) Quality assurance and Control
(e) Installation & handling

(a) Functional: A number of functional requirements are to be met in the design to facilitate a large size of irradiation volume, high / low dose rates, systems for irradiation under different temperature and atmospheric conditions, sensing of irradiation temperature, rotation of sample etc as detailed below.

- **Size of irradiation volume – diameter & height.**
- **Dose rate – Activity, source configuration.**
- **Dose uniformity.**
- **Through put.**
- **Shielding.**
- **Handling & installation.**
- **Servicing & maintenance**

To achieve above in practice, a designer usually starts with a given set of parameters having to do with the amount of product volume to be treated, the dose desired and dimensions of the unit product. From these, one determines the amount of source activity required to effect the treatment and then decides upon a geometric configuration between the source and the target that most efficiently or most economically satisfy the functional requirements.

In view of this, Radiation Technology equipment will consists of following main systems:

(i) A radioactive source, such as Co-60 or Cesium-137
(ii) Biological shielding
(iii) Mechanism of conveying the target into and out of irradiation field
(iv) The target or product
(v) Control and safety devices

These equipment can be also called gamma irradiator. Gamma Irradiators are classified in four categories as per international standards depending upon the storage of source and method of irradiation as indicated in annex-2. The exact design of various systems of different categories of irradiator will vastly vary from one another types as per the throughput, size of product and method of irradiation (continuous or batch type). For example for a compact and portable irradiator, a shielding material of high density like steel, lead, and tungsten would be more suitable while for a large size commercial irradiator concrete would be preferable and economical. The choice of source (cobalt-60 or cesium-137) is dependent upon its availability, specific activity, energy, size of the source and its geometrical configuration. Generally Cobalt-60 is being used for most of the irradiators due to its availability in large quantities in the required metallic & non-dispersible form and high penetrating power over cesium-137. The conveying system of product / samples into and from radiation field depends upon size of the product, throughput etc. as per the category of the irradiator and generally batch type or continuous type of conveyor systems are in use. Therefore, while designing, a detailed studies and analysis are needed to be carried out to optimize the functioning of various systems of the irradiator for effective utilization of the source & equipment so that cost of irradiation is economical and viable.

(b) Regulatory & Safety: Compliance of mandatory safety regulations and its tests for safe transportation of radioactive materials as stipulated in national and international safety standards are very necessary and essential to meet in the design apart from its functional requirements. These regulatory requirements are very severe and stringent and are based on hypothetical accident conditions of transportation. Only when the design meets the above regulations it is certified as Type B (U) package by the regulatory authority which permits the shipment of the package in public domain other wise the

equipment can not be transported & supplied. Some of the major regulatory requirements that are to be considered in the design are indicated below:

Mechanical (Drop) Tests: The equipment/package need to be dropped onto a hard unyielding target (a steel cum concrete block of minimum 10 times heavier than package) through a height of 9m followed by a second drop through a height of 1 meter on a steel punch of 15 cm diameter rigidly mounted on the above target.

Thermal Test: Following the above two drop tests, the same package is subjected to a thermal/fire test of 800 degree centigrade for 30 minutes, to assess the overall structural integrity of the package. This test is normally done in a suitably designed furnace or in open air fire having systems for controls of fuel supply, temperature and data recording.

Water Immersion Test: In this test, the package is immersed under a water head of at least 15 meter for about 8 hours and the structural integrity of the specimen are further examined for leakage of radiation. This test is conducted in a tank by subjecting it under hydraulic pressure.

Temperature Criteria: It is ensured that the mechanical strength and properties of materials of construction remain suitable for the above mechanical (drop) tests in the temperature environment range of - 40 to + 55 degree Centigrade. This stringent temperature criteria permits only a very few selected types of materials of construction for equipment.

Acceptance Criteria: After going through the above tests the acceptance criteria is that the shielding loss shall be limited to the extent so that the cumulative effect of mechanical and thermal tests should not cause radiation level to increase beyond 1 R/hr (10 mSv/ hr) at 1 meter distance.

Therefore, the above tests simulates a very severe accident conditions of transportation and if the design meets these performance criteria it is called Type B(U) package and its transportation can be affected anywhere with in the public domain. Without obtaining Type B (U) certificate from the competent authority i.e. Atomic Energy Regulatory Board (AERB) it is not possible to transport any radioactive material at any place.

(c) Manufacturing:

Manufacturing of equipment after its development is taken by adopting standard manufacturing codes. Material of construction and manufacturing processes are carefully selected considering the regulatory and functional requirements so that the products are not only fabricated of high standard as per the specifications but also manufactured economically.

(d) Quality Assurance & Control:

A very stringent quality control and assurance programme is adopted during design, manufacturing and commissioning of these equipment to assure a consistent high quality product supply to the users as per the approved drawings & specifications. During the process of development, the design is evaluated and validated by testing models and prototypes. During manufacturing a strict quality control programme is adopted as per codes to ensure use of right raw materials, processes, and other related tests. Further, the units are installed and commissioned by trained & experienced BRIT personnel and a training to users is imparted in operation and preventive maintenance for the smooth & safe functioning of the unit. A complete documentation on design, manufacturing and their tests is generated for each type of equipment for traceability of any information at a later date.

EQUIPMENTS DEVELOPED (Click for details)

BRIT had developed high capacity, large and medium sized self shielded type irradiators called **Gamma Chamber 5000**

(click) and **Gamma Chamber 1200 (Click)** for research and development purposes. It has also developed recently a dedicated c0balt-60 based **Blood Irradiator (BI-2000, click)** for the specific use of Irradiation of blood and blood products and low dose irradiation(Table-1 and Annexure-1). These equipment are Type B(U) approved by Atomic Energy Regulatory Board (AERB), India and a number of them are in use in the country and abroad.

A high capacity Cobalt-60 Irradiation cum source storage flask has been developed called **FP-100K** (Annexure – 3A) which is Type B(U) approved for Panoramic Batch Irradiator (**PANBIT**) for housing and exposing source up to 100 kCi inside a concrete shielded room. PANBIT is basically a Panoramic Batch Irradiator having dry source storage facility of capacity of 100 kCi with a shuffle dwell conveyor system. It is a multipurpose type irradiation facility intended to be used for research & development as well as pilot scale studies. It is particularly suitable for low product holdup time (6-10 hrs) and low to medium throughput having low budget allocation. It provides four sided irradiation unlike two sided irradiation normally available in commercial irradiators and hence gives a much better dose uniformity. It would be very useful for a small entrepreneur where often the requirement of product volume is low and is of varied nature. The facility can be setup in a minimum built-up area of approximately 160 square meters (Annexure – 3B).

BRIT has also developed a remotely operated Radiography Camera called **ROLI-1** (Click) using Iridium – 192 source (Annexure -4A) for application of non-destructive testing (NDT) of welds and materials. The camera has been designed and tested as per the requirements of ISO-3999 – 1977 and a number of these units are in use in industries (Annexure- 4B). It is provided with tungsten collimators to facilitate panoramic & directional exposures and enhanced operational safety. ROLI-1 camera has earned a status of workhorse in NDT industry

and there are presently about 390 of them are in use constituting about 48% market share in India.

CONCLUSION

With vast experience in the design, manufacturing, installation and commissioning of the radiation technology equipment developed over a period of time, it is possible for BRIT to design, develop and produce custom built equipment / irradiator to meet user's requirement at competitive cost. BRIT is presently embarking on the development of light weight and compact Cesium-137 based Blood Irradiator **(BI-1000 CS)** for irradiation of blood and their products in hospitals and blood banks and depleted uranium shielded light weight portable radiography camera **(DUCAM – 75)** of high capacity to provide more range of products and to meet the growing & varied demands of the users.

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Annexure-1

FEATURES OF GAMMA CHAMBERS AND BLOOD IRRADIATOR

- **Safe and self shielded**: No additional shielding is required. The radiation field on the external surface of the unit is much below the permissible level
- **Dose uniformity**: Stationary source pencils symmetrically placed in a cylindrical cage ensure good uniformity of radiation field within 25% variation.
- **Sample rotation Mechanism**: Sample rotation mechanism provided for better uniformity of dose.
- **Control system**: PLC based control system with touch sensitive color screen having user friendly software and printer for data recording in BI 2000 unit.
- **Automatic Dose & Decay correction**: Computerized Cobalt-60 source decay correction for dose rate, calculations of dose and corresponding setting of irradiation time.
- **Display of Irradiation Temperature**: Sensing of irradiation temperature and display on the panel
- **Door Interlock:** Sample chamber door inter lock for safety of operation by providing proximity sensor.
- **Service sleeves**: 4 nos. of 8mmØ ID service sleeves provided to sample chamber for manual control of irradiation temperature.
- **Design Standards**: Design conforms to codes of Atomic Energy Regulatory Board (AERB), India, as well as American National Standards – ANSI-N.433.1 – 1977 for safe design and use of self contained dry source storage Gamma Irradiator (Category-I).
- **Safety assurance:** The unit is **Type B(U)** approved by Atomic Energy Regulatory Board (**AERB**), India for safety in transport of radioactive materials as per relevant national and international safety standards.

Annexure-2

Categories of irradiators based on storage of radiation source & method of irradiation

CATEGORY- I : SELF CONTAINED, DRY SOURCE SORAGE IRRADIATOR.

- *The source is always located in the dry shield.*
- *The sample is moved in and out of the radiation field.*
- *At no time human access to source is possible*
- *American national standard institute. (ANSI) N 43.7.*

CATEGORY-II : PANAROMIC DRY SOURCE STORAGE IRRADIATOR.

- *Source fully shielded in dry storage when not in use.*
- *The source is exposed with in a radiation volume which is inaccessible during the irradiation.*
- *American national standard institute. (ANSI)N 43.12.*

CATEGORY-III :SELF CONTAINED, WET SOURCE STORAGE IRRADIATOR.

- *The source is shielded in the wet storage pool (usually water) at all times.*
- *The sample is moved in and out of the radiation field.*
- *American national standard institute. (ANSI)N 43.11.*

CATEGORY-IV : PANORAMIC, WET SOURCE STORAGE IRRADIATOR.

- *Source fully shielded in wet storage pool when not in use.*
- *It is exposed with in an irradiation cell which is inaccessible during use.*
- *American national standard institute. (ANSI) N 43.10.*

Annexure – 3A

PANBIT FLASK – 100 K(FP – 100K)

SPECIFICATIONS

- ***Source capacity*** ***: 100 kCi (3700 TBq) Cobalt - 60***
- ***Shielding material*** ***: Lead & SS 304 L***
- ***Weight of flask*** ***: 4800 Kgs. .***
- ***Size of flask*** ***: 920 mm x 920 mm x 1077 mm (ht)***
- ***Size of package*** ***: 1445 mm x 1445 mm x 1380 mm (ht)***
- ***Weight of package*** ***: 5500 Kgs.***
- ***Safety assurance*** ***:***

Type B (U) Approved by AERB, INDIA as per IAEA Safety series -ST-1, 1996 (as amended TSR-1, 2000) and AERB safety codes.

Annexure- 3B

PANBIT FACILITY

SPECIFICATIONS

- ***Max.Co-60 source capacity : 100 kCi (3700 TBq)***
- ***Cell size : 3 mts x 3mts x 3 mts***
- ***Labyrinth width : 1.2 mts***
- **Irradiation floor area : 95 Sq. mts**
- **Minimum built up area Of facility : 160 sq. mts**
- **Source : Cylindrical cage of 400 mm height x 100 mm dia**
- **Product box conveyor : shuffle dwell conveyor (Batch type)**
- **Product box size : 39 cm x 39 cm x 40 cm (ht)**
- **Dose uniformity : 1.4 at o.1 gm/cc of product density**
- **Throughput : 425 Lts / batch every 6 hrs at 25 kGy dose at 100 kCi loading**
- **Processing rate : 425 Lts per batch**
- **Operation : Remote operation through electrical control (Manual & automatic)**
- **Ventilation : 20 Air changes / hr**
- **Safety : Provided with interlock and fail safe mechanism**
- **Power supply : 440 V, 3 phase, 50 cycles AC – 4 wire system**

The units at SCTMC, Thiruvanthapurm & Jakarta (Indonesia) are in operation since last 20 years.

Annexure- 4 A

RADIOGRAPHY CAMERA (ROLI – 1)

I. Product Specifications:

- Isotope : Iridium – 192
- Half Life : 74 days
- Maximum Capacity : 1.3 TBq (35 curies)
- Testing range : 10mm to 70 mm of steel or equivalent
- Shielding Material : Lead
- Camera Operation : Remote control, Teleflex cable drive
- Maximum operating distance : 8 mts from camera
- Front guide tubes : 3 mts and 1 mt long (one (2 nos each)
- Overall dimensions : 37.5 cm x 25 cm x 27.5 cm (ht)
- Weight : 37 kgs.

II. Salient Features:

- Reliable and cost effective.
- Designed to operate with minimum maintenance
- Designed to conform to the requirements of class (M) exposure device in accordance with ISO/3999/1977 (E) and also to meet the requirements of Type B(U) radioactive packages as per AERB code SC/TR-1, Nov.86
- The source remains locked in the camera until the drive system is connected properly.
- Drive cable can be disconnected only when the source is in safe position
- The source can not be driven out unless the front guide tube is properly connected with the camera
- The safety interlock system ensures arresting the source in safe position

- **The source displacement can be monitored at the control unit.**

III. Supply of ROLI-1 : 390 no. of units are in use in various industries within India constituting 48% of market share. It costs around Rs. 1.5 lakhs.

Annexure – 4B

Summary of Tests Results of ROLI-1 Camera

ROLI-1 has been tested to meet the requirements of ISO - 3999 1977 (E) / AERB SS-1 for class (M) radiography device.

	Tests as per ISO 3999. 1977 (E)	Dose measured and Projected for 35 Ci 50 mm from surface	Permissible Dose rate stipulated for class M mobile
1.	Shield test	35 mR/hr	100 mR/hr
2.	Vibration test	32.66 mR/hr	100 mR/hr
3.	Horizontal shock test	36.95 mR/hr	100 mR/hr
4.	Vertical shock test	34.15 mR/hr	100 mR/hr
5.	Vertical shock test class M Mobile	32.89 mR/hr	100 mR/hr
6.	Endurance test	50000 Cycles	50000 Cycles
7.	Kinking test	OK	OK
8.	Crushing test	OK	OK
9.	Tensile test	1000 N	1000 N
10.	Accidental drop test – 9 Mts	36.53 mR/hr	1000 mR/hr
	Accidental drop test – 1 Mts		
11.	Thermal test (Type B (U))	975.0 mR/hr	

Supply Status of Radiography Cameras

Year	ROLI	Imported Cameras	Remarks
1993-1997	239	609	• ROLI-1 regular Supply started in 1993 • About 240 cameras are being serviced annually since 2002 onwards
1998	41	120	
1999	32	32	
2000	25	32	
2001	14	8	
2002	12	8	
2003	10	Nil	
2004 December	17	Nil	
Total	390	809*	~ 48% of Indian market share

* Basis AERB