Development of Indigenous, Remotely Operated, Portable Radiography Exposure Device (ROLI-3)

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Abstract

This paper describes the development of an indigenously made portable Industrial Gamma Radiography Exposure Device (ROLI-3). The source housing for the exposure device consists of hybrid shielding with heavy alloy and lead. Based on the philosophy of weight reduction through a combination of heavy alloy, lead and distance shielding, an optimum design of the exposure device is evolved. It weighs around 25 kg. It has been approved for 20 Ci of Ir-192 radioactive source by the Atomic Energy Regulatory Board having satisfied with the design requirements of an exposure device and also requirements of transport package, as per national and international standards.

1. Introduction

Industrial Gamma Radiography Exposure Device (IGRED) is generally designed with lead or heavy density material for shielding. Here, an attempt is described on the use of heavy alloy, lead and distance as radiation shield for reducing the weight of the camera for a given source strength. The newly developed IGRED is called ROLI-3 which has maximum capacity of housing 20 Ci Ir-192. The design conforms to ISO 3999-1:2000(E) and AERB/RF-IR/SS-1 (Rev. 1), 2007.

2. Shielding Design

The different schemes followed in the design of the camera are detailed in Fig. 1.

![Fig. 1: Core Design for Radiation Shielding](image)
(a) Source Housing

The radioactive source assembly is housed in a stainless steel ‘S’ tube which is surrounded by lead and heavy alloy as shielding material. The ‘S’ tube and shielding material is positioned in a stainless steel container. This assembly is called source housing.

(b) External secondary container

External secondary container provides distance shielding and serves the purpose as an integral package for transport. Considering the two factors i.e combined shielding and distance shielding, suitable outer shell geometry was arrived to provide optimum shielding. This geometrical figure is then modified to suit structural requirements. The outer container is made of stainless steel and is designed to minimize the weight and to withstand the standard test conditions as per the national and international standards.

(c) Interlock mechanisms

The interlock mechanism secures the radioactive source holder assembly in the shielded position. When the source holder assembly is retracted with drive system, it gets locked at the safe position automatically and the locking lever prevents the forward movement of the source. Key operated lock safeguards against unauthorized operation of the exposure device. This interlock mechanism gives all type of safety during operation and retraction of the radioactive source in the exposure device.

(d) Driving system

The drive system is provided for remote operation and safe distance from the exposure device. It is designed to suit a Teleflex cable of Ø 4.7 mm for movement and coupling the source holder for exposure. The source movement can be monitored at the driving end and the source can be projected out only when the control unit is coupled with the source holder. The source movement is also restricted till the front guide tubes are connected. The safety aspects incorporated in the exposure device prevents unauthorized handling and accidental exposure.

4. Development process

A few nos. of prototype of ROLI-3 camera were fabricated to house maximum capacity of 20 Ci. Ir. 192 radioactive source. Since the weight was found to be 26.8 kg, it is further modified to optimize the shielding as described in shielding design and attained to 25 kg approximately. During the horizontal shock test as per the standard, the outer container was not withstanding the impact. This was modified by making spherical side cover with proper fixing supports. The interlocking mechanism was also modified to meet the requirements of the safety features. A key operated

3. Design Description

Final design of the exposure device has been arrived at taking into various considerations for meeting the requirements of standards. [1][2]. The exposure device consists of four parts:

WP1 = WL1 + WS1
WP2 = WL2 + WS2 + WS3
WP3 = WH + WL3 + WS4 + WS5 + WS6
WP3 < WP2 < WP1

Where,

I = Surface dose rate on P1 or P2 or P3
K = K factor – dose rate per meter/curie
µ1 = Absorption coefficient of lead
µ2 = Absorption coefficient of steel
µ3 = Absorption coefficient of heavy alloy
L1 = Lead thickness of P1
L2 = Lead thickness of P2
L3 = Lead thickness of P3
S1 = Steel thickness of P1
S2 = Inner steel thickness of P2
S3 = Outer steel thickness of P2
S4 = Steel thickness of heavy alloy cladding of P3
S5 = Steel thickness of lead cladding of P3
S6 = Steel thickness of outer most casing of P3
WP1 = weight of P1
WP2 = weight of P2
WP3 = weight of P3
WL1 = weight of lead core of P1
WL2 = weight of lead core of P2
WL3 = weight of lead core of P3
WH = weight of heavy alloy of P3
WS1 = weight of steel casing of P1
WS2 = weight of inner steel shell of P2
WS3 = weight of outer casing of P2
WS4 = weight of steel cladding of heavy alloy
WS5 = weight of steel cladding of lead core
WS6 = weight of steel cladding of the outer most casing

An optimization technique is employed to see that the weight of P3 is less than P1 and P2. A modeling approach is employed to arrive at the optimum value of ‘B’. ‘L3’ and ‘H’. An outer cover provided of stainless steel 304 quality to provide the strength for the device to meet the requirements of the safety and transport standards.

The design principle also takes into account, the problems of fabrication, in order to keep the cost of the device reasonable. The core has been designed with regular geometry for the ease of fabrication.
standard Godrej lock was also introduced in to the interlock mechanism to avoid unauthorized operation. Finally with all the requirements BRIT could transform a portable radiography camera suitable for the industrial use in NDT field.

5. Performance tests

A prototype unit has been subjected to the following tests as per the standards. [1][2]

(i) Shielding efficiency test

This test requires demonstration that the stray radiation levels outside the exposure device, when containing a source with activity equal to the maximum design capacity of the device, does not exceed the limits given in the standard.

(ii) Endurance test

The endurance test is intended to check the resistance to fatigue and wear of different components after 50,000 cycles of operations.

(iii) Projection resistance test

The test is carried out to demonstrate the maximum force which shall be applied to the control lever (handle) of the drive unit to move the source assembly from the secured position to the working position and return it to the secured position.

(iv) Lock breaking test

This test is performed to check that the exposure container lock withstands a breaking force when it is locked condition with the key removed. The lock shall remain operational and effective after having undergone the test.

(v) Handle, attachment part or lifting mount test

The test determines that each carrying handle, attachment part or lifting mount is able to withstand a static force equal to 25 times the weight of the exposure container.

(vi) Vibration resistance test

The purpose of this test is to determine the natural frequencies which are characteristic of the exposure container and study the change in these natural frequencies in order to determine if the exposure container is able to withstand vibrations experienced during transportation.

(vii) Horizontal shock test

The test requires demonstration that the exposure device will withstand the horizontal impacts, it is likely to experience during use.

(viii) Vertical shock test

The test is intended to demonstrate that the exposure device will withstand the vertical impacts, it is likely to experience during use.
The test is intended to demonstrate that the exposure device will withstand hypothetical accident condition without exposing the source assembly.

(x) Stacking test

The purpose of this test is to prove that there is no loss or dispersal of radioactive content and no loss of shielding when the exposure device is subjected to a compressive load of 5 times the mass of the actual package for a period of 24 hours.

(xi) Penetration test

This test is intended to demonstrate the ability of the exposure device to withstand when a bar of 3.2 cm Ø having 6 kg mass with a hemispherical end dropped from a height of 1m.

Tests on remote control device and projection sheaths

(i) Kinking test

This test is intended to demonstrate that the remote control and projection sheaths withstand the stress that it may undergo as a result of kinking forces that may occur during setting up of the remote control for use.

(ii) Crushing and bending test

The test is intended to demonstrate that the control cable sheaths and projection sheaths withstands crushing and bending by the heel of a person’s footwear.

(iii) Tensile test

The test is intended to demonstrate that the control cable sheath, control cable, connectors and projection sheaths will withstand the tensile stress which may be experienced during use.

Test on source holder assembly

(i) Tensile test

Tensile test on source holder assembly requires demonstration that the source assembly will retain its integrity after experiencing tensile loads likely to be applied during use.

6. Design Approval

The approval of Atomic Energy regulatory Board has been obtained for this exposure device to house a maximum strength of 20 Ci of Ir-192. This exposure device is also approved as Type A package for transportation as per IAEA Safety Standard Series No TS-R-1 (ST-1), 2005. The specifications of the exposure device are given in Table 1.

<table>
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7. Concluding Remarks

ROLI-3 is simple in design and economical in construction. It is portable, compact and easy to operate. Considering the difficulties in importing an exposure device, ROLI-3 is bound to offer a very attractive and also alternative to the users in India.

The new concept has enabled to achieve a camera of medium capacity with minimum weight. However, further improvement is possible to reduce the weight below the present value and increase the capacity.

References