# Shielding Processing Technique through the Calculations and Measurement of the Time Averaged Cross-Section of Multiphase Domain

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## Abstract

The dual source computed tomography (DSCT) setup has been developing in the central and has potential for use as anon-invasive tool for determining the time averaged cross section of multiphase domain. The two sources used in (DSCT) setup are located inside source collimator device (SCD) to collimate the beam to give it a fan shape. The count rate of un-attenuated photons will be measured by two sets of detectors. Radiation shielding is based on the principle of attenuation, which is the ability to reduce a wave?s or ray?s effect by blocking or bouncing particles through a barrier material. Charged particles may be attenuated by losing energy to reactions with electrons in the barrier, while gamma radiation is attenuated through scattering, or pair production. . Calculated results showed a substantial convergence with the real measurement values of dose rates especially in the common points.

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***Index terms***— Shielding, Arrays, Scanning, Dose rate, Time averaged.

## 1 Introduction

adiation can be a serious concern in gamma-ray systems, containing radiation and preventing it from causing physical harm to employees or their surroundings is an important part of operating equipment that emits potentially hazardous rays. Preserving both human safety and structural material that may be compromised from radiation exposure are vital concerns, as well as shielding sensitive materials. The process of regulating the effects and degree of penetration of radioactive rays varies according to the type of radiation involved. Indirectly ionizing radiation, like gamma ray is categorized, which involves charged particles. Different materials are better suited for certain types of radiation than others, as determined by the interaction between specific particles and the elemental properties of the shielding material. The DSCT unit is a research machine designed to quantitatively determine the time averaged of multiphase flow systems.

It has been designed to use two sealed point gamma ray sources **??**1, 2, 3, and 4]. Currently, it is equipped with Co60 (~50 mCi) and Cs137 (~300 mCi).

Each source is housed in a Source Collimator Device which is made of lead (for Cs137) and tungsten (for Co60). A fan beam arrangement of source-detectors is used for measuring the transmission of the gamma ray photons across the multiphase experimental setup **??**5, 6, 7, and 8]. The fan beam consists of a longitudinal section of a cone. Each point gamma ray source is placed at the vertex of a cone. Its detector array is placed along the bottom section of its cone and the multiphase experiential setup is placed in the middle. The sources are positioned at the geometrical center of their SCDs to provide maximum shielding. The setup is designed so that the multiphase experimental setup placed at the center is simultaneously exposed to gamma photons from both sources. A detector array is located at the side opposite to each source in the respective fan beams. These arrays are capable of counting the un attenuated photons or even the scattered photons of the gamma ray that pass through the multiphase experimental setup. Typically a window of energy is set and the counts that fall in this window are recorded. Before a DSCT experiment is be performed, it is first ensured that the multiphase experimental setup is operating at the desired conditions. The SCDs are opened, to turn on the source. The DSCT experiment called a scan is then started and typically runs for about 8 hours. At the end, the SCDs are closed to 'turn off' the sources. During the scan, for a given source position, the detectors array is made to move in an angular manner. For each motion, the computer and data acquisition system collect the gamma ray counts data. The detector plate is moved 21 times; hence, the 15 detectors are oriented at 21 angular positions each with respect to the source. This way, for a given position of the source, 315 angular positions are covered along the arc of the fan beam.

# 2 II.

# 3 Materials And Methoeds

a) Gamma ray sources and the Collimator Devices (SCDs)

Figures (1)(2)(3)(4)(5)(6)(7)(8)(9)(10)(11)(12) are for equipments used in Fulton Lab. The Source Collimator Devices (SCDs) were designed by Dr. Charles Alexander at Oak Ridge National Laboratory (ORNL) as a part of the DOEanaerobic digester grant and manufactured by the Machine Shop facility at ORNL **??**9, 10, 11, 12, and 13]. Lead was used for the Cs 137 SCD, and tungsten was used for the Co 60 SCD [3]. The gamma ray beam emerges from the collimator window, which is always shut with a window wedge when the source is not in use. The wedge is secured by a wedge pin **??**14, 15, 16, and 17] as shown in Figure 1. The point source is located inside the lower half of an arming rod. In use, the arming rod is at the axial center of the SCD. Figure **??** shows the disassembled SDC. The window wedge is placed so that its apex occupies the axial center of the device, the location the source will be lowered to when the source is to be 'turned on' or 'opened'. Figure 3 shows the SCD partially assembled and labels the window through which the gamma ray beam appears. This window is perfectly aligned with the detector lead collimators when the SCD is mounted on the DSCT setup. The source device has a wedge pin as a security device. To 'open' the source, the wedge pin is first removed. The window wedge is then removed with pliers. The top plate cover is removed by loosening the bolts attached to it. The removal of the top plate cover makes the plug retaining plate accessible. This plug retaining plate is attached to the arming rod that has the source in it. This externally threaded plate is lowered with a custom tool until the source is in the lower section of the SCD and centered in collimator window is in the lower section of the SCD and centered in collimator window. b) Gamma ray sources and the Collimator Devices (SCDs)

The following shielding components are used in the DSCT setup. 1. Source Collimator Device (lead or tungsten) **??**18 and 19]. The Source Collimator Devices (SCDs) are 6 inches in diameter. The closest distance from the outer surface of the SCD to the source is source is 3 in. for Cs 137 and 3.5 in. for Co 60 . Hence, these are the minimum shielding thicknesses of the SCDs Tungsten collimator for the Co 60 has an additional lead shield of ½ in. thickness. 2-External Beam Collimator (lead): External Beam Collimators have been attached to each of the SCDs with the aid of annex tension from the upper section of the collimator strap, so that they are in line with the collimator window, as shown in Figure **??**. These collimators, 2 inches in length at their center, make the gamma ray beam shorter in height as it emerges from the collimator window. Collimators have an aperture in the center. Two different sizes of apertures are used (small and large). The small . assuming the concrete walls and the doors are absent, and the fan beams are directly oriented towards the wall. The wall thickness and an additional distance of 30 cm (11.81 in.) have been considered to determine the distance for these calculations as shown in Figure 12. The shielding by the NaI crystal in the detector has been accounted. Since attenuation data for parts of the detector excluding the crystal was unavailable, attenuation by the crystal alone has been included. DSCT operation the public dose is calculated to be less than 2 mrem/hr. sight of the source when it is "turned on". These dose rates will be received, if one is .Since the dose rates calculated here doesn't account for the shielding from the block walls doors, and the multiphase experimental column in the center of the DSCT setup, the measured values will be less than 1mrem/hr in any one hour . Dosimeters will be placed on the walls on the North, the West and the South sides, and on the mesh on the East side such that they are in line with the DSCT set up. These will record the dose received at the periphery of the room due to the DSCT experiments. These dose records will be a good estimate (after accounting for attenuation by the walls) of the public dose rates. These dosimeters will be returned every quarter to Radiation Safety, and the new ones issued will be placed at the same location. Dose rates related to closed SCDs when the source is 'turned off'. These doses will be received in the region behind the SCD even when the source is 'turned off' DSCT radiation workers must conduct instrument surveys monthly and after any CT work, and must document these results properly. There must be no more than a 30 day gap between monthly surveys. If the lab contains no radioactive materials (RAM) or sealed sources, but the lab is still on active status as defined by radiation safety, it is still required to perform and document monthly lab surveys. The instrument surveys are used to detect radiation and to identify areas of contamination. Radiation workers must routinely survey the place of work and themselves individually, both during and after their work. The areas to be surveyed are: areas of radioactive material use and storage, components of the DSCT setup, experimental setup and its components, and the equipment used with the DSCT instrument. Radiation survey instruments are available in areas where sealed sources/devices are used. In these laboratories, there are two different types of portable Geiger-Muller (G-M) surveymeters: one is a Bicron Model 50 with cylindrical G-M probe, and the other is a Ludlum Model 3 with a pancake G-M probe. Instrument surveys are valuable in identifying areas where radioactive contamination may be present and surveying the radiation field around the sealed sources/devices. In a typical survey, dose rate measurements are made in the vicinity of the sources /devices and throughout the laboratory. In addition, these portable survey instruments are used for a variety of general tasks: 1. To conduct routine area surveys of the laboratory. 2. To confirm the successful opening and shutting of the collimator containing the sealed source.

3. To survey shipments of sealed sources received.

4. To monitor hands, shoes, clothing, and the work area for contamination before leaving the area. G-M instruments are widely used for radiation survey work because of their reliability and low cost. The Bicron G-M probe is suitable for measuring exposure rates (mR/hr) in the vicinity of radioactive sources, but is relatively insensitive for detecting low levels of radioactivity associated with contamination. The Ludlum pancake G-M probe is much more sensitive to low levels of radioactive contamination, and the open side of the detector can be used for surface contamination measurements in counts per minute (cpm). The back side of the detector can be used like any G-M probe for exposure rate or dose rate measurements (mR/hr or mrem/hr). Figure 13 shows the Ludlum model3 survey meter with the pancake probe for general-purpose surveying. 2. Red Beacon: A red beacon is fitted on top of the DSCT's computer tower. This is connected to a sensor box, placed on the circular source table (Figure 1). When either of the SCDs is opened to 'turn the source on' the sensor detects the radiation and the beacon is turned on. This sensor is set at threshold of 2 mrem/hr. Distance can be as simple as handling a source with forceps rather than fingers. c-Shielding: Biological shield refers to a mass of absorbing material placed around the radioactive source, to reduce the radiation to a level safe for humans. The effectiveness of a material as a biological shield is related to its cross-section for scattering and absorption, and to a first approximation is proportional to the total mass of material per unit area interposed along the line of sight between the radiation source and the region to be protected. Almost any material can act as a shield from gamma or x-rays if used in sufficient amounts. Experimental work as shown in Table **??** which presents the concentrations of the radiation of sources 235mCi Cs 137 and 22mCi C0 60 for twenty five locations using gamma ray tomography. Doses for locations onethirteen when the two sources closed are between 0.01-0.05 mR/h. The Doses for these points when the Cs 137 source is opened are between 0.02-0.05 mR/h, but the doses when the Co 60 source is opened are between 0.02-0.07mR/h. When the two sources are in work, the maximum concentration is at point 6 as shown in Figure 12. Table **??** presents the equivalent dose for locations 1ft far from the two sources at points fourteen-twenty one, the maximum dose rate is at point eigteen when the two sources are in work. Table 4 presents the doses rates for locations twenty two-twenty five for locations far 3ft from the view plate, so the maximum dose rate is at point twenty four and equal to 1.5 mR/h when the two sources are active in work. **??**igures 15,16,17,and 18 shows that the results obtained using the Ludlum Model 3 Survey Meter with Model 44-9 G-M Pancake Probe and electronic pocket dosimeter instrument(EPD TM ) Figures 19 and 20 shows that the equivalent dose rates in (mR/h) and (rad/h) in 3-D. The calculation dose rates induced by Cs 137 and Co 60 sources as shown.The maximum dose rates when 235mCi Cs 137 source is active in work is 1 mR/h at a distance (1ft) far from view plate for points 14,15,16,17,18, **??**9, **??**0, and 21 as shown in Figure 12, the dose rates for these points are 0.8,0.5,0.5,1,0.4,0.4,0.3 and 0.4 resp. For points ate distance of (3ft) far from view plate, the minimum dose is 1 rad/h, while the maximum dose is 0.5 rad/h. Other locations 1-13 as shown in Figure 12 , the dose rates are between 0.02-0.03 rad/h, these doses are low and not affected on human health. Dose rates recorded by 22mCi Co 60 source is lower than the rates of Cs 137 source. When the two sources are in work, all doses are reached the maximum values near the view plate as shown in Figures 18, 19, and 20. So we can say that the doses are at the maximum limits when the two sources are in work around view plate. Gamma ray is the form of electromagnetic radiation that occurs with higher energy levels than those displayed by ultraviolet or visible light.

There are several factors that influence the selection and use of radioactive shielding materials, such as attenuation effectiveness, strength, resistance to damage, thermal properties, and cost efficiency can affect radiation protection in numerous ways. So materials with high density are more effective than the low density for reducing the intensity of radiation. Low density materials can compensate for the disparity with increased thickness, which is as significant as density in shielding applications. Lead is particularly well suited for lessening the effect of gamma rays due to its high atomic number. This number refers to the amount of protons within an atom, so a lead atom has a relatively high number of protons along with a corresponding number of electrons. These electrons block many of the gamma ray particles that try to pass through a lead barrier, and the degree of protection can be compounded with thicker shielding barriers.

# 4 Results And Discussion

Radiation protection can be divided into occupational radiation protection, medical radiation protection, and public radiation protection. There are three factors that control the amount of dose like; a-Time: Reducing the time of an exposure reduces the Radiation can be a serious concern in nuclear power facilities, industrial or medical x-ray systems, radioisotope projects, particle accelerator work, and a number of other circumstances. Containing radiation and preventing it from causing physical harm to employees or their surroundings is an important part of operating equipment that emits potentially hazardous rays. Preserving both human safety and structural material that may be compromised from radiation exposure are vital concerns, as well as shielding sensitive materials. The process of regulating the effects and degree of penetration of radioactive rays varies according to the type of radiation involved. Indirectly ionizing radiation, which includes neutrons, gamma rays, and x-rays, is categorized separately from directly ionizing radiation, which involves charged particles. Different materials are better suited for certain types of radiation than others, as determined by the interaction between specific particles and the elemental properties of the shielding material. Through Figure **??**2, we see that the standard deviation has the highest value in the case of open the two sources , so we see some points are out the domain of the probability lines, while we see that the standard deviation is less when we open the cesium source and the value becomes half when we open the cobalt source. From Figures 23 and 24 ,we see that the blue area is for the sites 15-20, these areas are widely exposure to gamma rays ,so we advise workers not to work for long periods within this region. The theoretical calculations as shown in Figures 25 and 26 ,we see there is a strong match between theoretical calculations and measurement processes up to 95% when the two sources are open, which confirms the correctness of theoretical calculations which we made.

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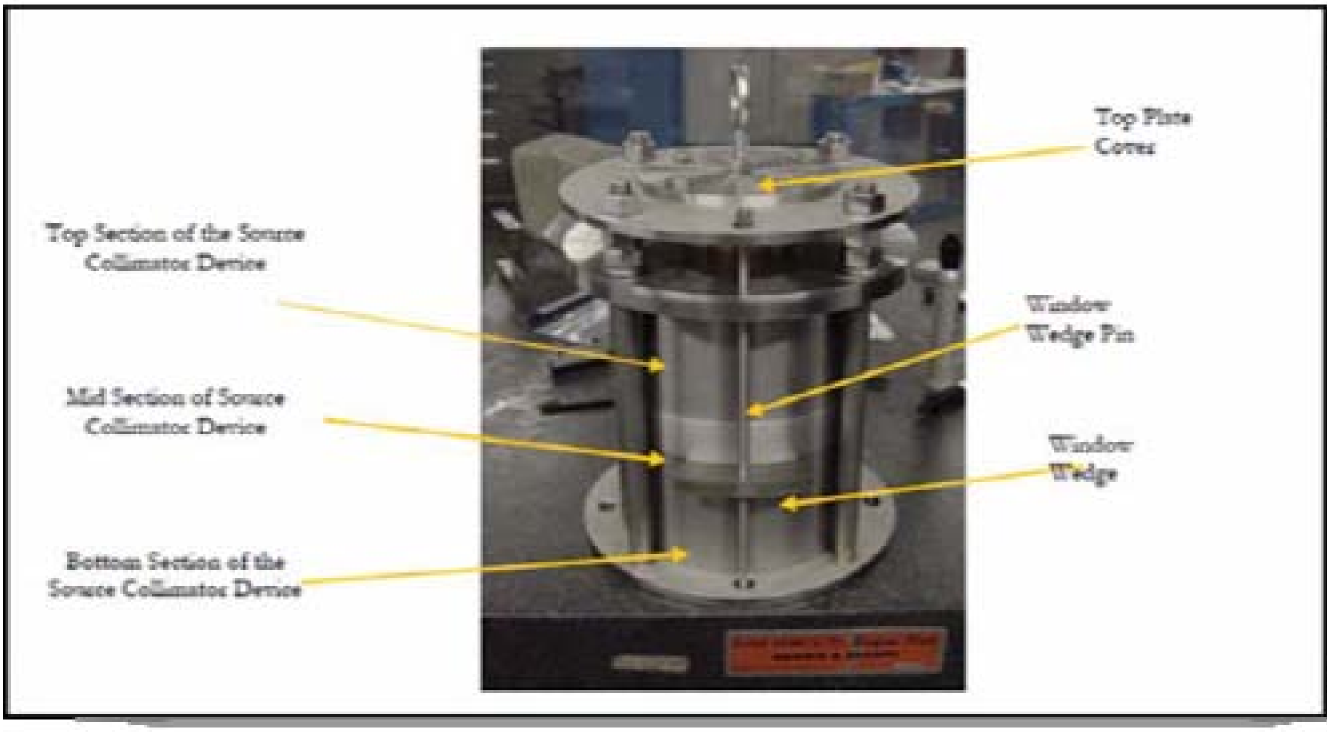
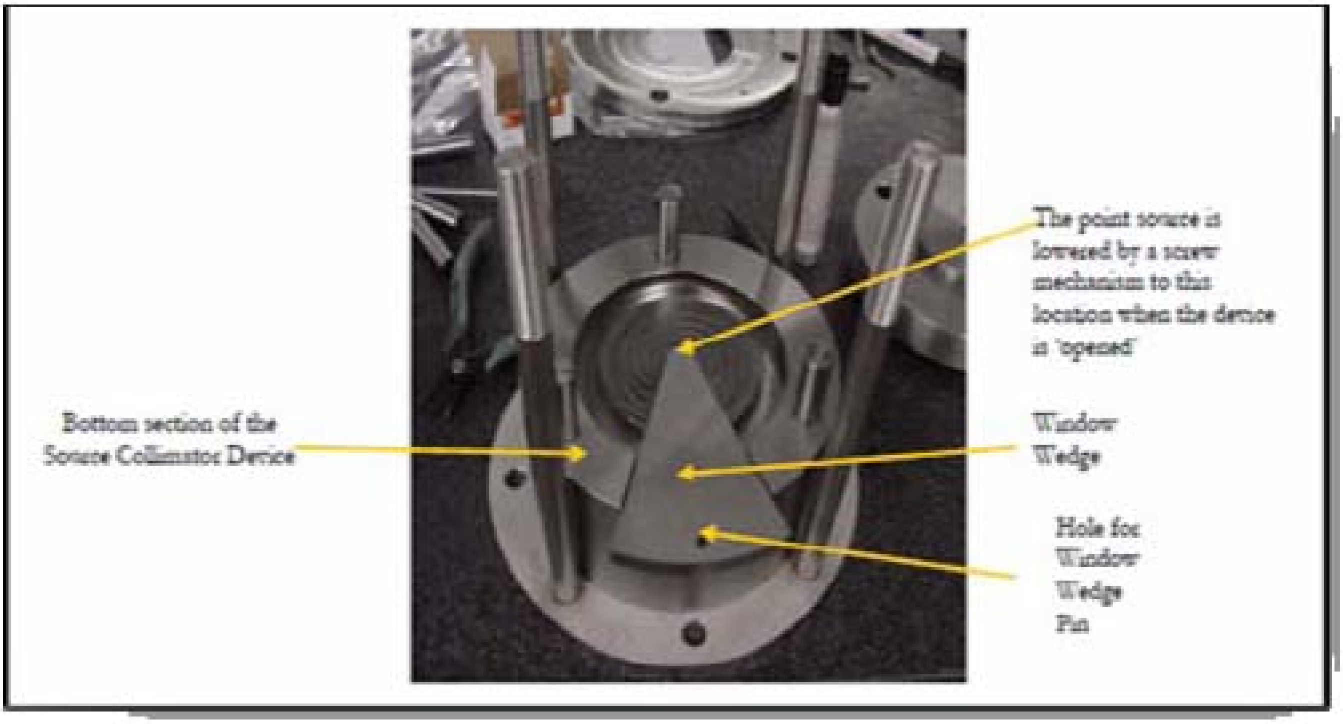
Figure 1: Fig. 1 :



**234**

Figure 2: Fig. 2 :Fig. 3 :Fig. 4 :



**56**

Figure 3: Fig. 5 :Fig. 6 :

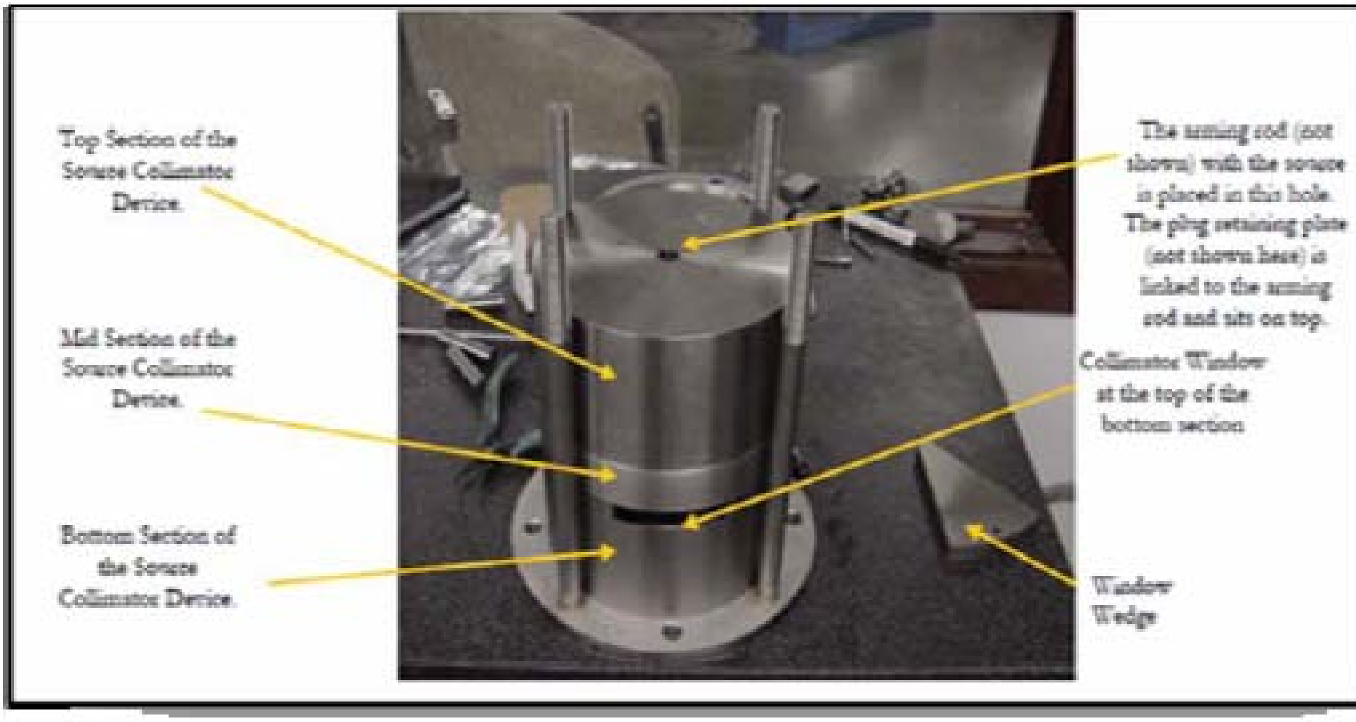


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Figure 4: Fig. 7 :

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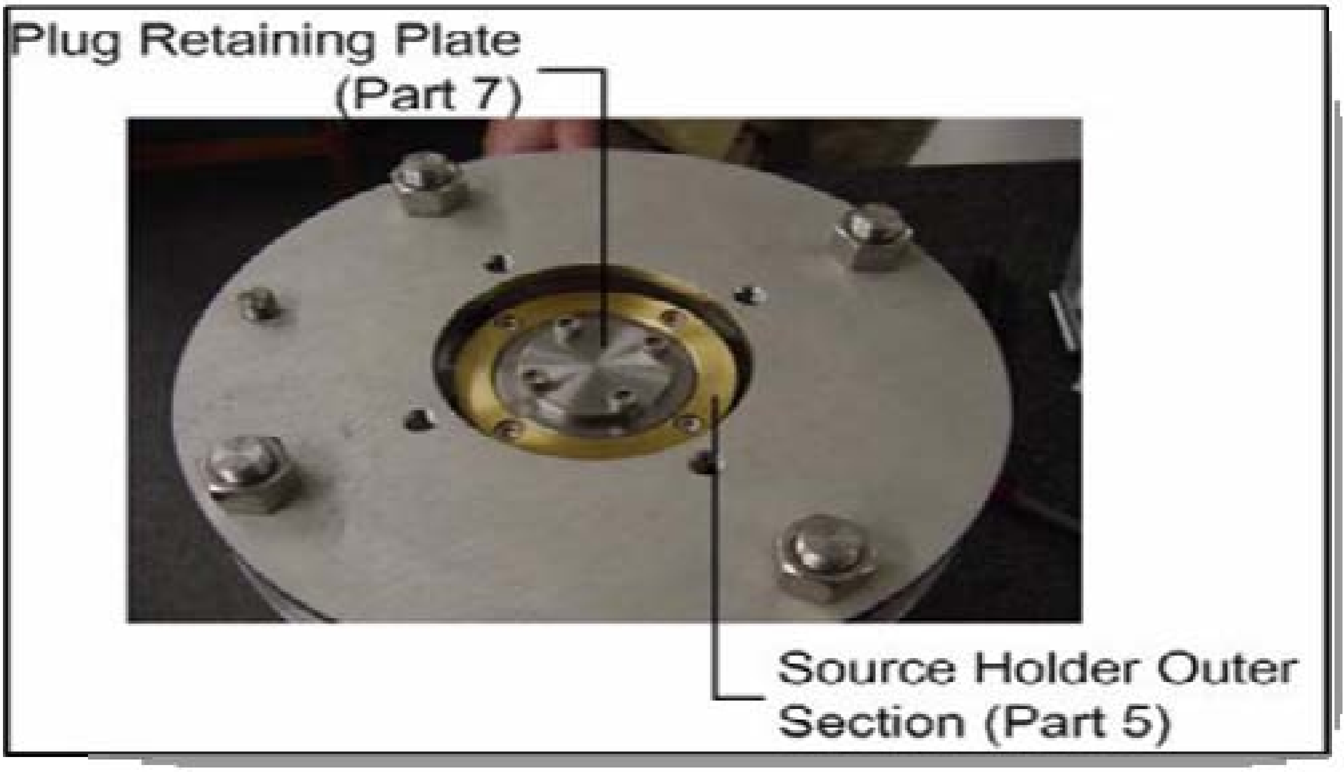
Figure 5: Fig. 8 :Fig. 9 :Fig. 10 :

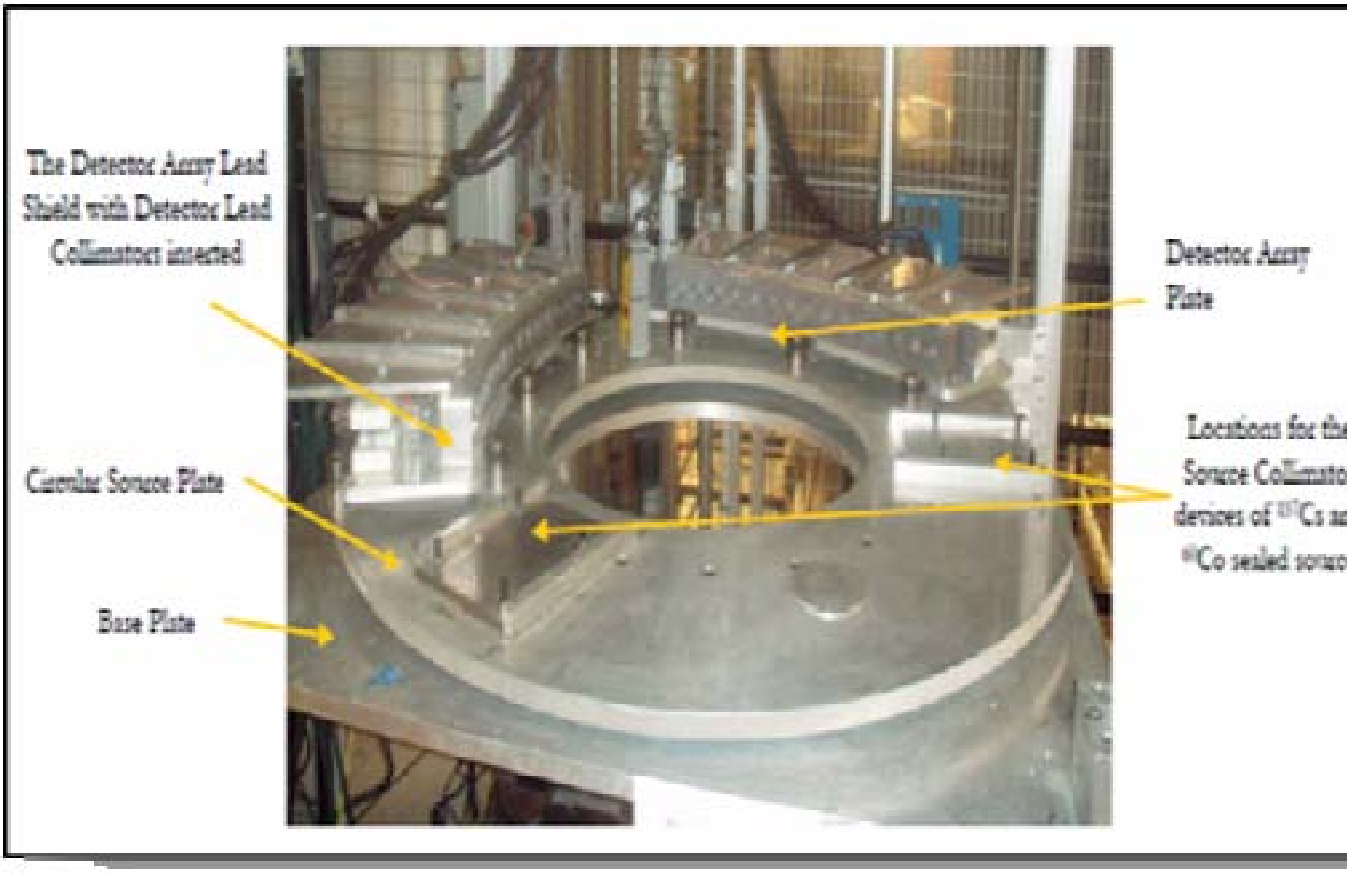


**11**

Figure 6: Fig. 11 :

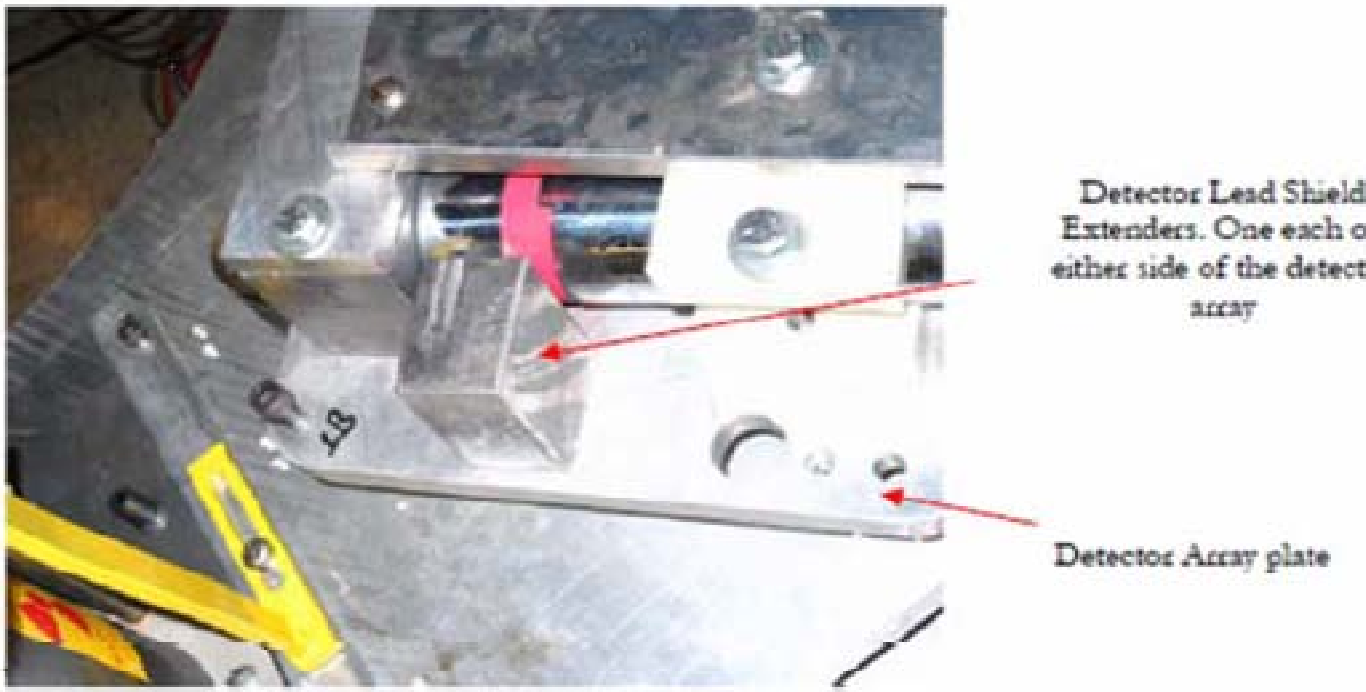
**13**

Figure 7: Fig. 13 :



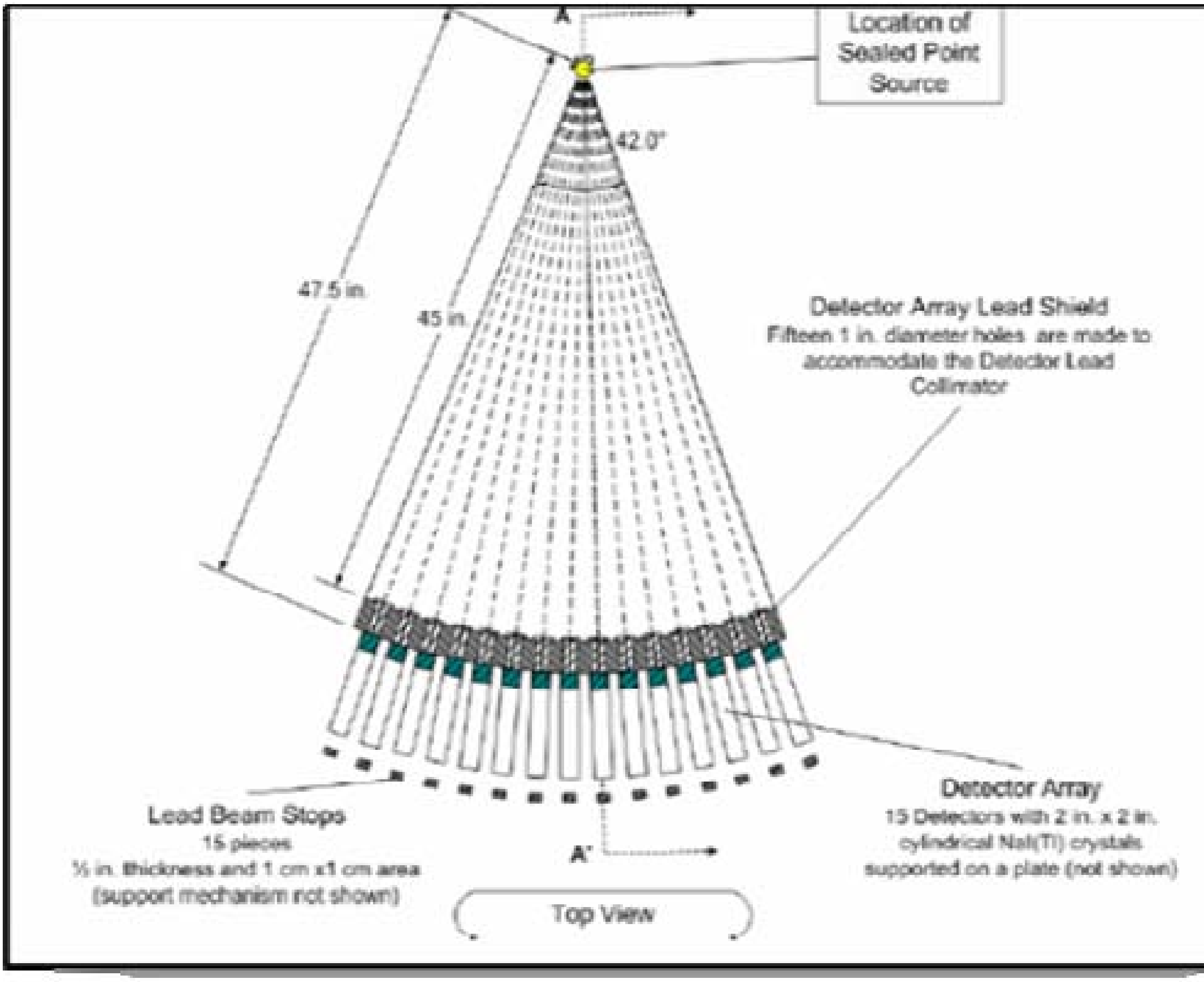
**14**

Figure 8: Fig. 14 :



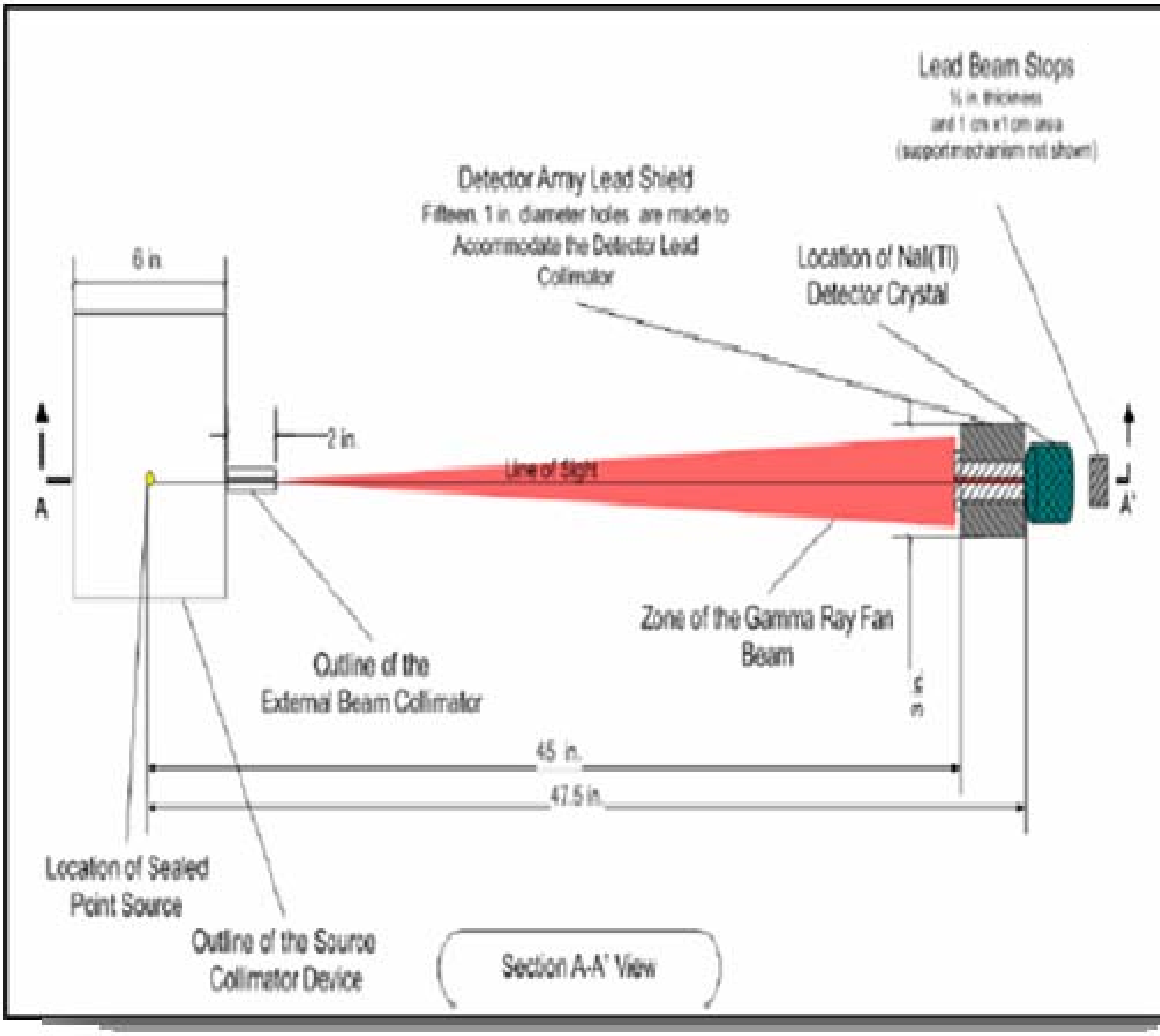
**3**

Figure 9: 3 .



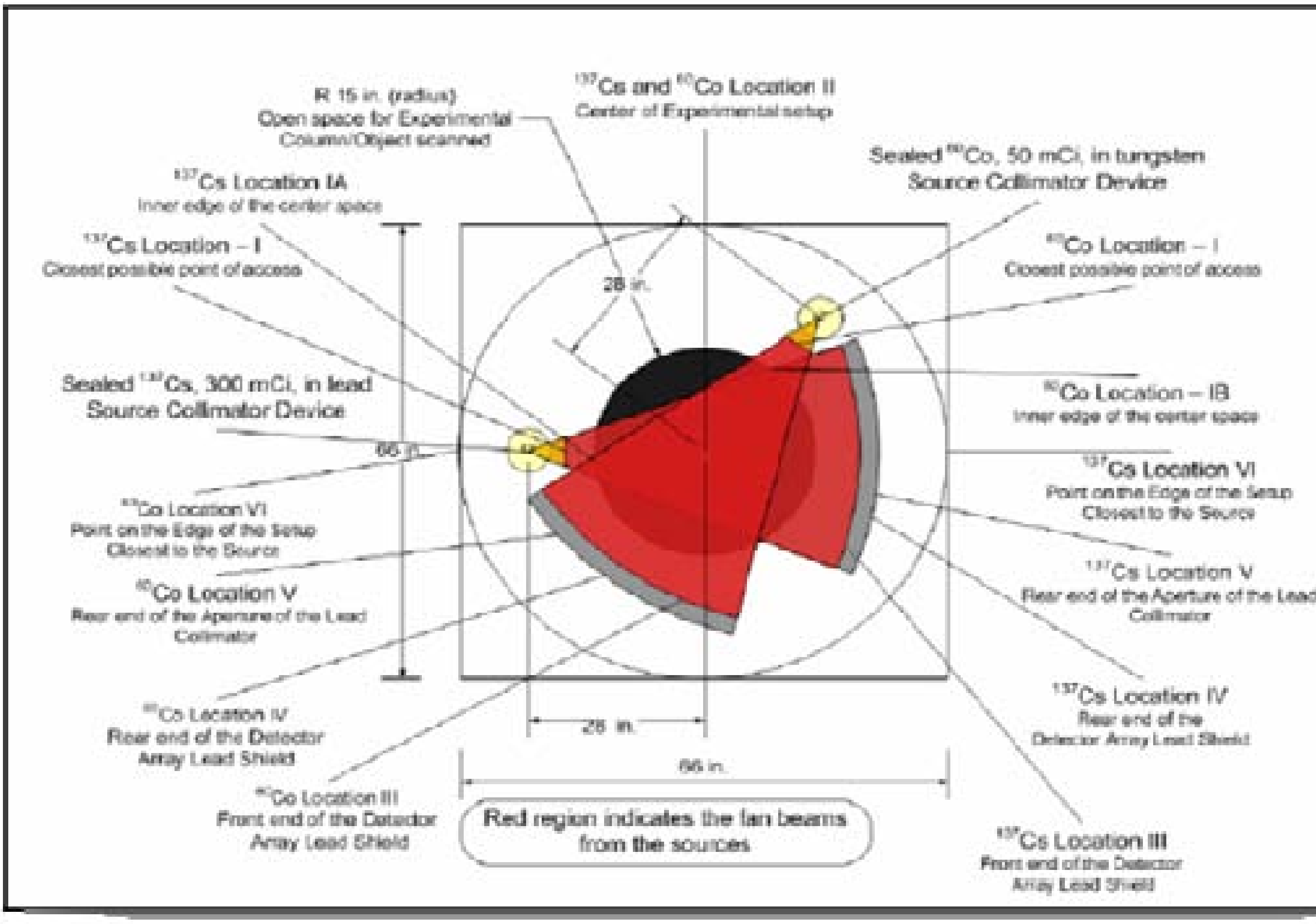
**1515**

Figure 10: Fig. 15 :Fig. 15 :



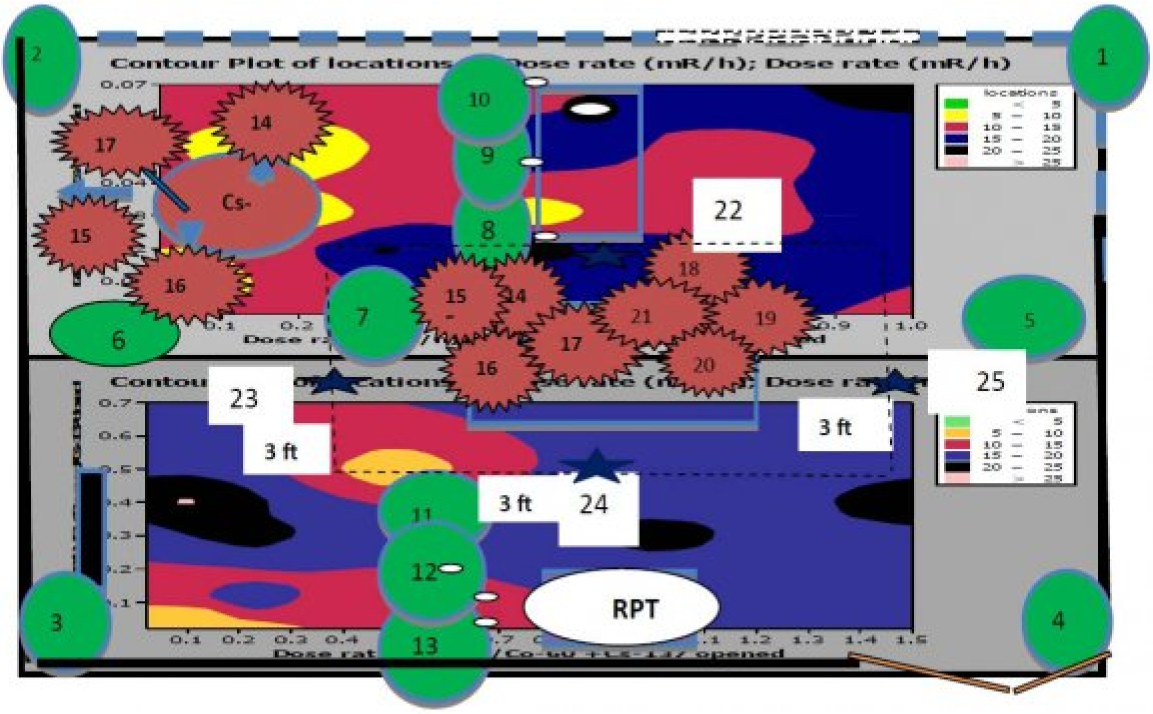
**16**

Figure 11: Fig. 16 :



**18**

Figure 12: Fig. 18 :

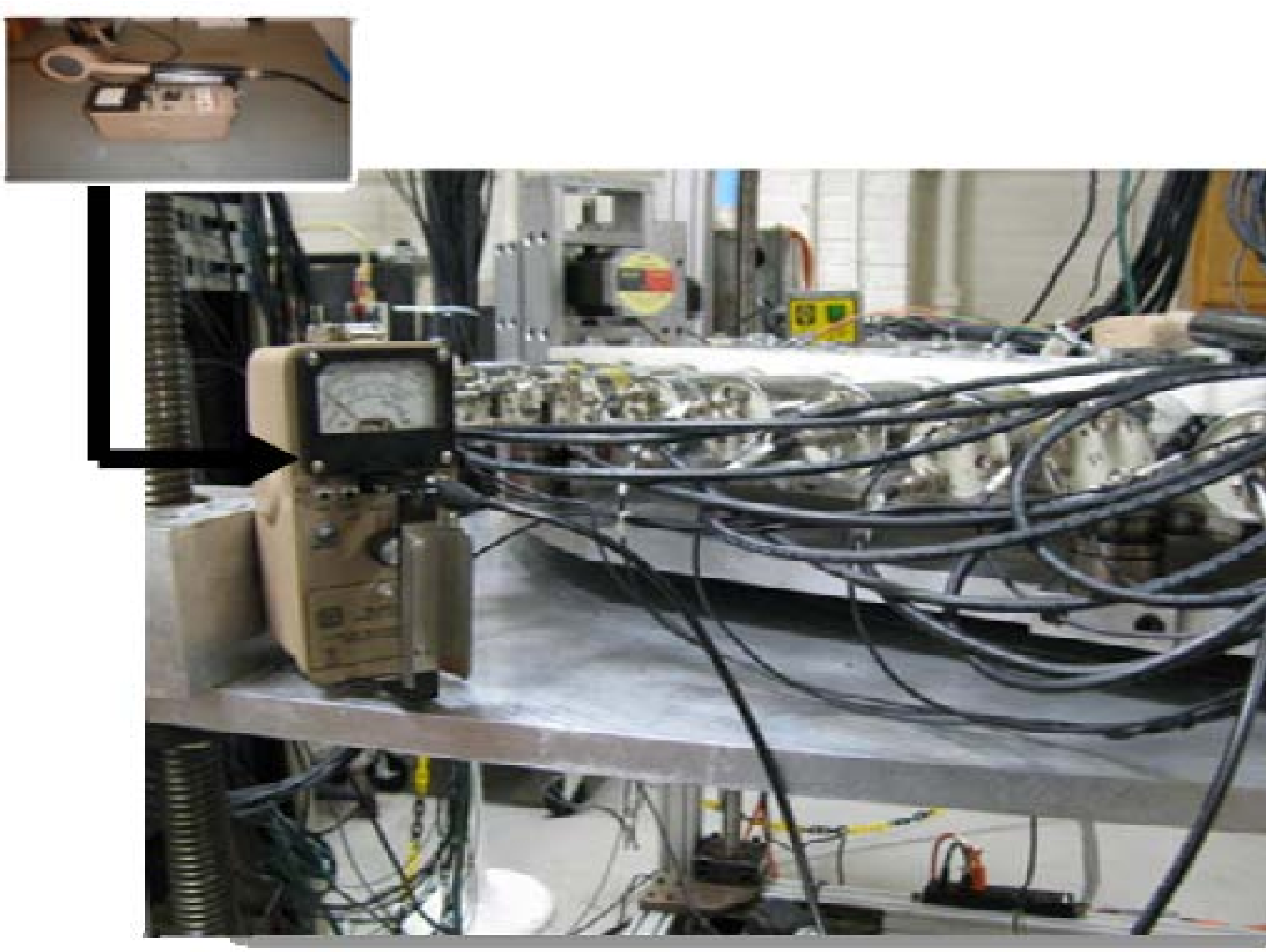


**21**

Figure 13: Fig. 21 :

**23** [redacted]

Figure 14: Fig. 23 :



**26**

Figure 15: Fig. 26 :

**1**

Figure 16: Table 1 :

| Location | Dose rate closed (mR/h) /Cs-137 | Dose closed rate (mR/h)/ Cs-137 /Co-60 opened | Dose closed rate (mR/h) /Co-60 opened/ Cs-137 | Dose rate (mR/h)/ Co-60 + Cs-137 opened |
|---|---|---|---|---|
| 1 (around) | 0.01 | 0.02 | 0.02 | 0.02 |
| 2 (around) | 0.01 | 0.02 | 0.02 | 0.02 |
| 3 (around) | 0.01 | 0.02 | 0.05 | 0.02 |
| 4 (around) | 0.01 | 0.02 | 0.03 | 0.02 |
| 5 (around) | 0.03 | 0.5 | 0.02 | 0.2 |
| 6 (around) | 0.03 | 0.2 | 0.07 | 0.1 |
| 7 (around) | 0.05 | 0.2 | 0.5 | 0.5 |
| 8 (around) | 0.01 | 0.05 | 0.02 | 0.05 |
| 9 (around) | 0.03 | 0.03 | 0.02 | 0.02 |
| 10(around | 0.02 | 0.02 | 0.02 | 0.02 |
| 11(around | 0.01 | 0.02 | 0.02 | 0.05 |
| 12(around | 0.03 | 0.02 | 0.03 | 0.02 |
| 13(around | 0.00 | 0.02 | 0.02 | 0.02 |
| 14 (1 ) | 0.05 | 0.8 | 0.1 | 0.07 |
| 15 (1 ) | 0.05 | 0.5 | 0.2 | 0.06 |
| 16 (1 ) | 0.05 | 0.5 | 0.1 | 0.08 |
| 17 (1 ) | 0.05 | 1.0 | 0.1 | 0.08 |
| 18 (1ft) | 0.02 | 0.4 | 0.4 | 1.5 |
| 19 (1 ) | 0.01 | 0.4 | 0.7 | 1 |
| 20 (1 ) | 0.02 | 0.3 | 0.4 | 1 |
| 21 (1 ) | 0.02 | 0.4 | 0.3 | 1 |
| 22 (3 ) | 0.05 | 0.5 | 0.1 | 0.2 |
| 23 (3 ) | 0.02 | 0.5 | 0.3 | 0.2 |
| 24 (3 ) | 0.02 | 0.5 | 0.4 | 1.5 |
| 25 (3 ) | 0.07 | 1.0 | 0.4 | 0.1 |

Figure 17:

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*[Note: Fig. 25 : Plot of calculated dose rate]*

Figure 18: Table 4 :

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