COLLIMATOR DETECTOR EFFECT ON DESIGN OF THE RADIATION PORTAL MONITOR IN GAMMA RADIATION DETECTION TEST ACCORDING TO SNI IEC 62244:2016


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Abstract

BRIN’s RPM is made from NaI(Tl) Sodium iodide crystal scintillators detectors. Due to the certification process, RPM was tested based on SNI IEC 62244:2016. This standard requires radiological tests in the form of gamma radiation detection tests by measuring radioactive statically or dynamically that are conducted by varying sources and distances. For calculating the variation of activity was using inverse-square law. This research was carried out in Serpong Nuclear Area – BRIN PUSPIPTEK. Three standards of radionuclide were used namely Am-241, Cs-137, and Co-60. In the static condition, the radionuclide source was placed in the midpoint of a distance of 2.4 m from each portal. In the dynamic condition, the source was moved through the detection area for the rate of passer-by (10 – 20 km/h). In both static and dynamic conditions, from 50 tests, a minimum of 49 alarms was triggered, the assuredness level was more than 95%. The counting results without using inverse-square law decrease with non-linear distance variations. It’s because the detector collimator opens only straight ahead causing an active area of the detector that received radiation to be smaller. The thickness of RPM’s housing frame also has a role in reducing the count value. The farther the measuring distance, the more did holder of the source blocking radiations received by the detector. This caused the different calibration factors for each counting.

Keywords: Radiation Portal Monitor, SNI IEC 62244:2016, radiological test, inverse-square law, calibration factor.

Abstrak


1. INTRODUCTION

In recent decades, the Nuclear industry increased significantly and used in a lot of fields such as medicine, non-destructive testing, computed tomography, and x-ray imaging. Transport radioactive through the ocean become an issue after the Fukushima Daichi tragedy in 2011. Significant amounts of radioactive nuclides were released directly into the Pacific Ocean. (Yoo et al., 2020) (Periáñez et al., 2021)

Security and safety issues are also the others concern in transport radioactive. National Research and Innovation Agency of Indonesia (BRIN) developed Radiation Portal Monitor (RPM) to prevent it.

RPM is a radiation detector designed to examine radiation sources carried by people or vehicles passing through the detection area. These facilities will be installed at checkpoints of port, airport, industry, and health facility to ensure security against the entry and exit of goods particularly related to nuclear material. (Nugraheni, 2016)

Indonesia has a lot of RPM, but all of them are imported. If there is some damage, we have to call the expert and it cost a lot. (Triyanto et al., 2016)

RPM prototypes that have been developed by BATAN are named RPM 16. RPM 16 was made from NaI(Tl) Sodium Iodide crystal scintillators detectors for counting the radiation of gamma-ray and stainless steel housing frame.

RPM prototype was expected to have increased detection sensitivity and reduce detection threshold for special nuclear material so that they can rely on the physical protection system. For those purposes, RPM has to be certified and pass the testing process (Triyanto et al., 2016)

Previous researches have been done for calculating the effectiveness of radiation portal monitor. Their research was conducted by changing the atmosphere and temperature range (Weiss et al., 2021), distance (Yoo et al., 2020), and speed (Schroettner et al., 2009).

In this research, due to the certification process, RPM has to comply with the standard requirement. The reference standard used is SNI IEC 62244:2016. This standard requires several tests to be applied, including radiological tests in the form of gamma radiation detection tests. Gamma radiation detection test is carried out by measuring radioactive statically or dynamically that conducted by varying sources and distances (BSN, 2016).

Aside from the test, standardization of RPM is also essential for uniformity in using and recording the alarm.

Therefore, the aim of this paper is for assuring if BATAN’s RPM meets the requirement of the gamma radiation detection test according to SNI IEC 62244:2016.

2. LITERATURE REVIEW

Gamma radiation detection test was carried out by measuring radioactive statically or dynamically that conducted by varying sources and distances. The aim of this test is for testing performances of RPM such as the ability to sound an alarm when the detector receives radiation (10 X Background) and measuring distance range due to the influence of the detector collimator.

For calculating the variation of activity was used inverse-square law. Inverse-square law is a law of Physics that is used in the distribution of activity of a physical quantity that falls in inverse proportion to the square of the distance from the source. (Fei et al., 2018)

Inverse-square law in the former research has been concluded as a good method in determining virtual electron sources’ location in X-ray linac with higher electron energies. (Douk et al., 2018)

The number of electrons is identical to the electron energy that is produced. The more electron number, the higher electron energy produced. (Sianturi, 2017)

In this research, electron energy was identical to the activity of the source. So, the equation used was:

$$A_1 \times r_1^2 = A_2 \times r_2^2$$

$$A_2 = \frac{A_1 \times r_1^2}{r_2^2}$$

Where “A” represents an activity in Becquerel and “r” a distance in meter.

3. EXPERIMENTAL METHODS

This research was carried out in Serpong Nuclear Area – BRIN PUSPIPTEK in the rear area of building 71. The reference standard used was SNI IEC 62244:2016.

Based on the standard the radiological test was carried out by gamma-ray radiation detection. In this research, three standards of radionuclide were used, namely Am-241, Cs-
137, and Co-60 which represent, low, medium, and high energy.

3.1. Static Conditions
Radionuclide source was placed in the midpoint of a distance of 2.4 m from each portal. For static conditions, RPM was considered to be accepted if the alarm sound occurs 49 times out of 50 times trials for each radionuclide test. For additional data research, response tests with variations of distance were conducted. Each source was shifted from the midpoint as far as 1 meter, along 1 till 5 meters (2.6 m; 3.1 m; 3.8 m; 4.7 m and 5.6 m).

The alarm must be triggered when the measure count rate is greater than the alarm setting. This requirement must be met over a continuous gamma energy range from 60 keV to 1.5 MeV. (tested with Am-241, Cs-137, and Co-60)

RPM 16 amplifier settings:
- R = 1100 Ω
- I = 0.9 mA
- Setting alarm (presence sensors) 10 X Background
- Minimum measurement capability 2 X Background

Setting background followed by conditions.

3.2. Dynamic Conditions
For dynamic conditions, the source was moved through the detection area for the rate of pass-by (10 – 20 km/h) for the particular type of RPM. Each radionuclide was moved through the midpoint of the detection section. RPM was considered to be accepted if the alarm sound occurs 49 times out of 50 times trials for each radionuclide test.

4. RESULT AND DISCUSSION
The experiment results for static conditions, from 50 tests minimum 49 alarms were triggered so that the data was obtained with more than 95% of assuredness level. Results of response tests with variations of distance can be seen in Figures 2 to 4.

![Figure 1. Portal monitor radiation illustration test](image1.png)

![Figure 2. Static response test result for Cs-137 from the experiment and with Inverse-square law correction](image2.png)

![Figure 3. Static response test result for Co-60 from the experiment and with Inverse-square law correction](image3.png)

![Figure 4. Static response test result for Am-214 from the experiment and with Inverse-square law correction](image4.png)
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REFERENCES


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