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Neutron Leakage From Polyethylene Slit

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A measurement of neutron dose rate on iron-polyethylene shielding structure was carried out by 252Cf source. Simulated geometry was slit-like opening of polyethylene in iron slab and polyethylene slab shielding.

These experiment was done at research facility of Hazama Co,. Iron slab and polyethylene slab thickness were 10cm each. A gap of the polyethylene was simulated. Neutron REM-counter, polyethylene covered BF3 counter (STUDSVIK 2202-D), was used for measurement of streaming neutron dose equivalent. The solid state track detector (SSTD), allyl-diglycol-carbonate, were used for measurement of fast neutron dose equivalent in the range of 170Kev to 15Mev.

The experimental data was obtained against gap width, source location and detector location.

Obtained data shows strong correlation between dose rate and above parameters.

These data was investigated in the view of to make use of actual facility design and compared with calculation such as MCNP4B.

From the result of gap streaming experiment and calculation, we obtained allowable gap width as 6mm for this case (10cm polyethylene thickness).

KEYWORDS: Neutron, shielding, streaming, iron, polyethylene, 252Cf,measurement, REM-counter, reprocessing facility, shielding design

I. Introduction

A nuclear facility with strong radioactivity such as nuclear fuel reprocessing plant requies massive shielding for radiation protection. These facilities have shielding door or port which was consisted of iron and polyethylene. polyethylene is used as neutron absorber because of its shielding effectiveness and its inexpensive cost.

However, polyethylene has a large volume expansion rate of temperature., Therefore, a gap is required between polyethylene blocks to avoid destruction.

Radiation streaming from that gap may occur. In the view of shielding design, It is necessary to estimate the dose from gap.

In order to estimate the leakage dose from gap, many studies have been carried out on calculation procedure[1, 2, 3].

At the same time, there are still remain the uncertainties of estimation of streaming radiation on complex geometry.

The purpose of this study is to obtain the measurement data of neutron leakage from polyethylene slit on the iron slab, and to obtain the allowable gap width with regard to manufacturing design.

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II. Experiment

An experiment was carried out using Iron and polyethylene slab of 10cm using 252Cf source. A gap of the polyethylene was modeled.

This experiment was done at research facility of Hazama Corporation.

1. The Experiment Set Up

The experiment set up section view are shown in **Fig.1**. The plan view is shown in **Fig. 2**.

252Cf source, its intensity was 2.73E8(n/s), was located under the iron slab.

The polyethylene slab was assembled using small bricks its dimension is 10*5*20cm. And, this polyethylene slab was located onto the iron slab.

Thickness of the iron and polyethylene slab is 10cm respectively.

Neutron REM-counter, polyethylene covered BF3 counter (STUDSVIK 2202-D), was used for measurement of neutron dose equivalent. The REM-counter was located close to polyethylene gap. We counted logical pulse output of REM-counter and converted it into neutron dose equivalent.

The solid state track detector(SSTD),allyl-diglycl-carbonate, were used for measurement of fast neutron dose equivalent in the range of 170Kev to 15Mev. The dimension of SSTD is approximately 0.5*1.0cm and 0.1cm thickness.

The SSTD plates were fixed on the measuring position using thin wooden rod and adhesive tape.

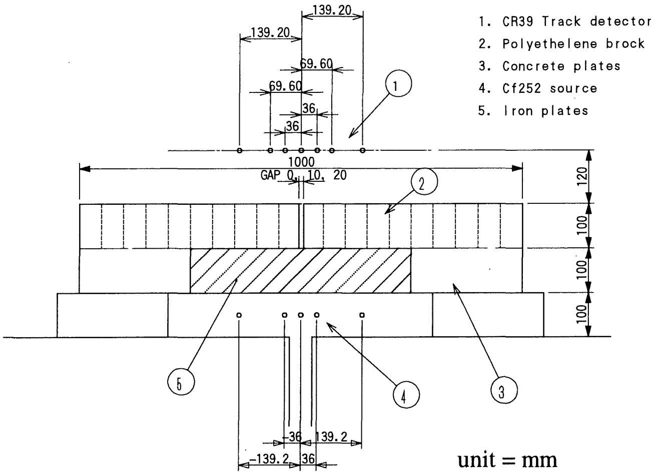

Fig.1 Experiment set up (section view)

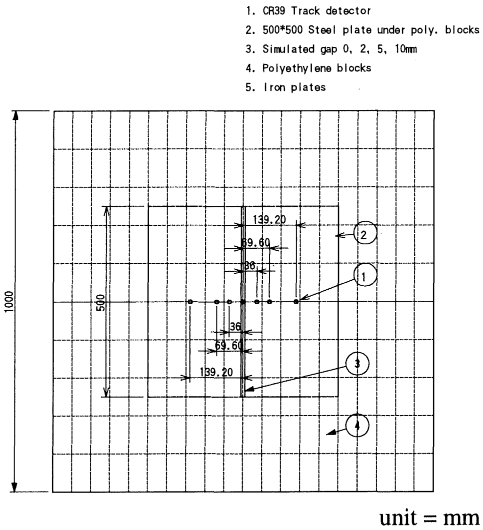

Fig.2 Experiment set up (plan view)

2. Measurement of the Gap Streaming Neutron Dose

Dimension of the simulated gap in the polyethylene slab is 2 to 20mm. This gap was made by moving the polyethylene bricks.

Neutron dose rate was measured by solid state track detector and REM-counter.

(1) Measurement using SSTD

The measurement setup using SSTD is shown in Fig.1 and Fig.2. The SSTD is small enough to measure the dose rate distribution near the polyethylene gap.

To investigate the character of neutron streaming from the gap in the polyethylene slab, we have changed three parameters.

The first parameter is horizontal distance of detector to the center line of the gap. We placed SSTD around the gap to obtain a dose distribution nearby the gap. The location of SSTD, that is expressed by the horizontal distance from center line of the gap, are 0,36,69.6 and 139.2mm.

The second parameter is gap width. To obtain the effect of gap width on leakage neutron dose, we set the gap width as 0, 10 and 20mm.

The third parameter is source position. The source position, that is expressed as the horizontal distance to the center line of the gap, had been set 0, +- 36 and +-139.2mm.

Vertical distance of SSTD to polyethylene surface is 12cm. This distance (12cm) is equivalent to the distance SSTD to the center of the REM counter.

These parameters are listed in the **Table 1**.

(2) Measurement using REM Counter

The REM counter measurement setup is shown in Fig.1 and Fig.2. That is same as SSTD measurement, but the REM counter was placed only just on the center line of the gap.

Two parameters was changed. The first is the gap width. The gap width was set as 0, 2 5, 10 and 20mm.

The second is source position. The source position, that is expressed as the horizontal distance to the center line of the gap, had been set 0, - 36, -69.6 and -139.2mm.

Table 1. Parameter setting of SSTD measurement

Parameter	value of the parameter (mm)			
Distance from gap to SSTD	0.0	+-36.0	+-69.6	+-139.2
Polyethylene gap width	0.0	10.0	20.0	
Source position	0.0	- 36.0	- 139.2	

III. Measurement Result

1. Result of Measurement using SSTD

As described previously, the parameters such as detector position, gap width, and source position was changed.

These parameters are listed Table 1 below. The purpose of this measurement is to obtain the data of neutron leakage around the gap in the polyethylene on the iron slab, and to investigate the allowable gap.

Measured fast neutron dose rate using SSTD are shown for each source position in **Fig.3** to **5** respectively. When 252Cf source is located just under the gap, relatively large dose was observed at just above the gap as it is shown in Fig.3.

On the other hand, Fig.5 shows very little leakage. As the source is moved away from the gap center, dose rate above the gap has decreased rapidly.

Figure 6 displays the same measured data at right above the gap, but in different manner that the horizontal axis represents the gap width.

2. REM Counter Measurement Result

REM counter measurement was also done as same as SSTD measurement, but REM counter was located just on the gap only. The parameters are listed in **Table 2**.

Measured neutron dose rate using REM counter are plotted versus the gap width in **Fig.7**. This graph is in the same form as Fig.6 that represents the SSTD measurement. However, these graphs are different from each other.

The first different point between Fig.6 and Fig.7 is the dose rate difference at the gap width 0mm. In another saying, 0mm

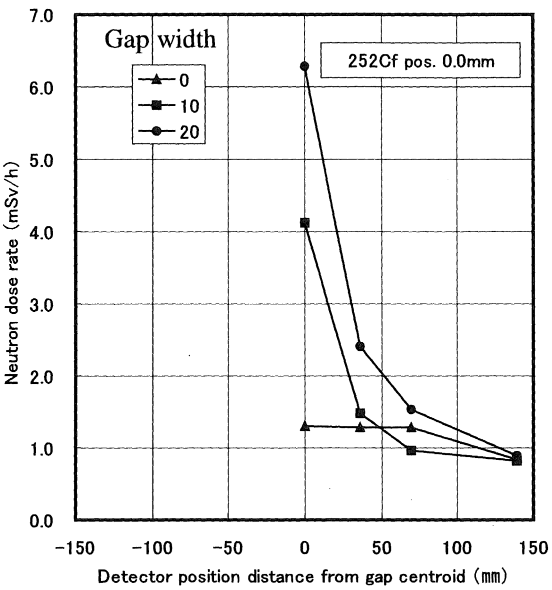

Fig.3 Neutron dose rate verses measuring position and gap width (source position = 0mm)

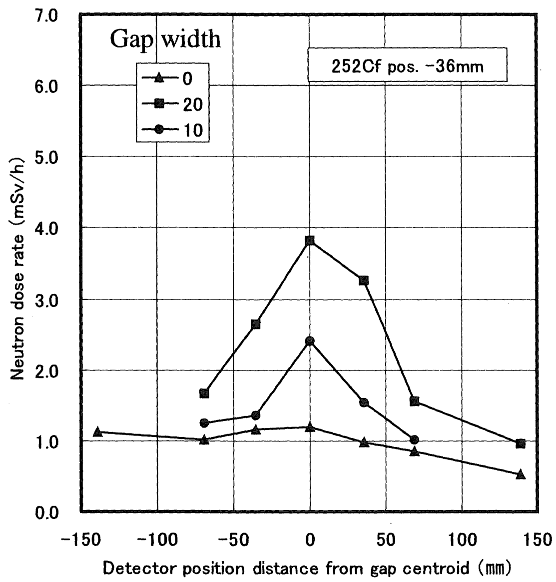

Fig.4 Neutron dose rate verses measuring position and gap width(source position = - 36mm)

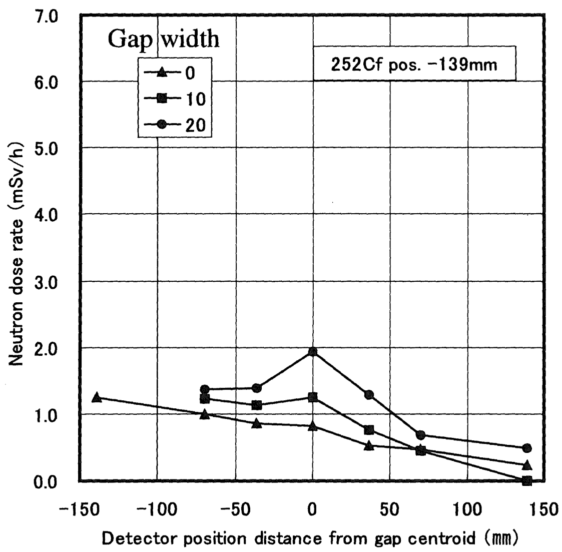

Fig.5 Neutron dose rate verses measuring position and gap width (source position = - 139mm)

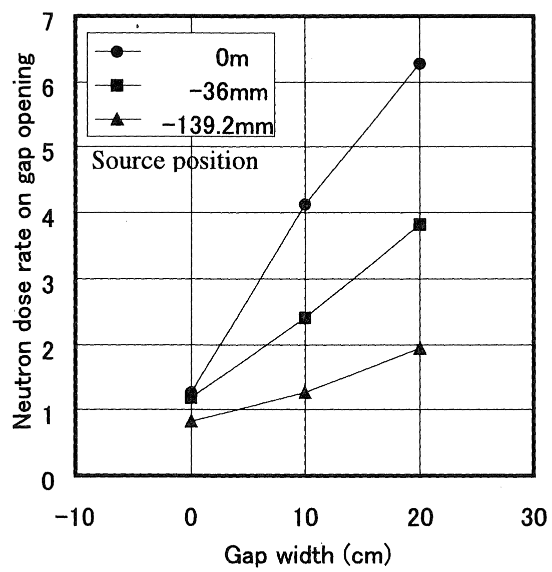

Fig.6 Neutron dose rate on gap opening verses gap width and source position

gap is simple slab. REM counter measurement is approximately 15% lager than SSTD. This discrepancy is due to low energy part that SSTD could not detect. The Monte Carlo code MCNP4B reproduces this difference as approximately 10%.

The second different point between Fig.6 and Fig.7 is the significant difference of dose rate when the gap width is wide as 20mm. Dose rate of SSTD measurement in Fig.6 was two times lager than REM counter measurement in Fig.7 when the gap width is 20mm. The reason of this discrepancy would like to be the difference of the size of detector. REM counter is large detector as sphere of 12cm radius. Therefore dose rate was averaged over its large sensitive surface area and it leads relatively small dose rate reading. On the other hand, SSTD is

Table 2. Parameter setting of REM counter measurement

Parameter	value of the parameter (mm)				
Detector (REM) position distance from gap	0.0 (just above the gap)				
polyethylene gap width	0.0	2.0	5.0	10.0	20.0
Source position	0.0	- 36.0	- 69.6	- 139.2	

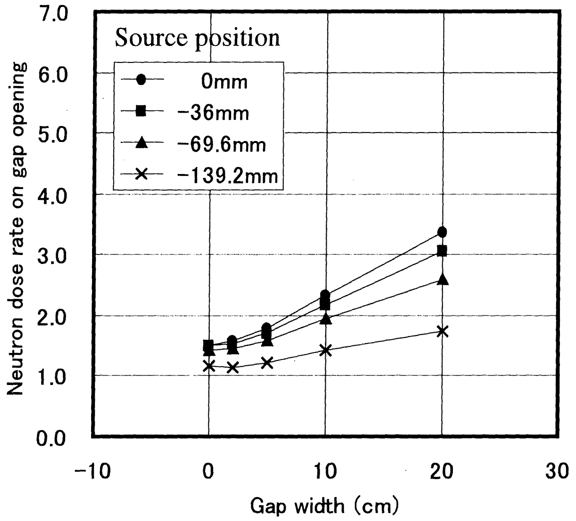

Fig.7 Neutron dose rate on gap verses gap width and source position

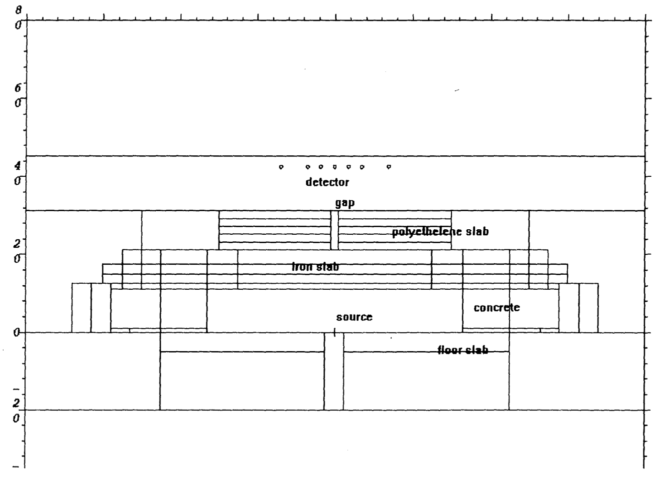

Fig.8 MCNP4B calculation model for gap streaming easurement by SSTD

small. Its dimension is rectangle of 5mm * 10mm. It is small enough comparing gap width, and hence, It could detect the peak of dose rate in the limited space.

IV. Reproduction of the Data by Monte Carlo Code

1. Procedure of the Calculation

Monte Carlo code for radiation transport and processor speed has been significantly improved. Therefore, recently, Monte Carlo calculation approach for shielding problem in facility design work becomes feasible. Los Alamos Monte Carlo code MCNP4B[(4)] is widely used and verified in many foundation. We have chosen MCNP4B from the reason that it has flexible geometry modeling capability, and it has reliable nuclear data.

The procedure of the calculation is described below.

1. Source spectrum

The built in watt's formula, that generates neutron spectrum of 252Cf, was used for this work.

2. Geometry description

We modeled the experiment set up as a whole. To take into account the effect of wall reflection, we also modeled room wall of experiment facility. **Fig.8** shows the center part of calculation model.

3. Tally

REM counter is very large to compare with gap width.

Hence, A surface flux tally was used to reproduce REM counter measurement. The shape and size of the surface tally is a circle of 12cm radius. It is approximately the same size as a moderator of REM counter.

On the other hand, cell volume flux tally were used for SSTD. The shape and the Size of the tally is a sphere of 0.4cm radius. It has the same projection area as SSTD.

The calculated flux were multiplied by dose equivalent response functions to do a comparison with REM counter and SSTD measurement data.

4. Variance reduction

A statistical variance reduction method [(6)] is important to obtain reliable result by Monte Carlo method in the limited time. We used a source emission direction bias that is expressed by exponential form, Geometry splitting and energy roulette.

Nuclear data used in this work was ENDF/B-VI based file[(5)] that was distributed with MCNP4B code.

2. Result of the Calculation

Calculation to Experiment ratio on REM counter measurement is shown in **Fig.9**. Fig.9 shows C/E ratio versus source position and gap width. C/E ratios become worse as the gap width become wider. It suggests simple surface tally is not complete simulation of REM counter.

MCNP4B calculation shows agreement with REM counter measurement. Its discrepancy is mostly less than 10%.

On the other hand, calculation and SSTD measurement is not in good agreement. Its discrepancy is mostly less than 20%. Some data shows over 30% discrepancy. The reason is not sure. We are considering the reason is due to sensitivity difference in incidence angle on SSTD. Our cell volume tally in this work could not take into account such a sensitivity difference in incident angle.

V. Discussion to use the Measured Data for Facility Design

A measurement of the neutron dose rate on iron-polyethylene shielding structure was carried out using 252Cf source. As the source is moved away from gap center, dose rate above the gap decreases rapidly. In another saying, if the angle between source and gap entrance is grater than 45 degree, Very little neutron leakage from the gap will be expected. Moreover, when the polyethylene gap width is narrow, neutron leakage from the gap will be negligible.

In a facility design work, we used to take a margin as approximately 2 times on a shielding calculation result. Therefore, we can accept additional streaming dose up to the margin that is mentioned above.

For example, if the target dose is A Sv/h. We design the slab thickness to achieve the leakage dose A/2 Sv/h. Therefore additional A/2 Sv/h can be allocated for another leakage such as streaming.

From Fig.7, The allowable width of the gap, when neutron dose becomes as same as 2 times of the dose of slab (width of the gap is 0mm), is 16mm.

On the other hand, from Fig.6, The allowable width of the gap, when neutron dose becomes as same as 2 times of the dose of slab (width of the gap is 0mm), is approximately 6mm.

This discrepancy is resulted from detector size as already discussed in section III.B. To satisfy both result, as a conclusion, We can assume that 6mm gap width is acceptable in the geometry of this work.

VI. Summary

A measurement of neutron dose rate on iron-polyethylene shielding structure was carried out by using 252Cf source. Simulated geometry was slit-like opening of polyethylene slab that was on the iron slab.

Neutron REM-counter, polyethylene covered BF3 counter (STUDSVIK 2202-D), was used for measurement of neutron dose equivalent. The solid state track detector(SSTD), allyl-diglycol- carbonate, were used for measurement of fast neutron dose equivalent in the range of 170Kev to 15Mev.

The experimental data was obtained against gap width, source location and detector location.

Obtained data shows strong correlation between dose rate and above parameters.

These data was compared with calculation result using MCNP4B. From the result of gap streaming experiment and calculation. We obtained the guide of design limitation of gap width as 6mm in this work (10cm polyethylene and 10cm iron slab).

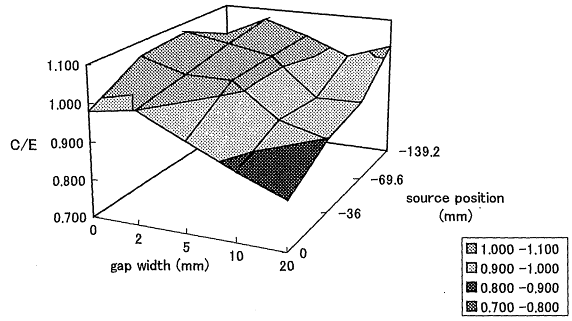

Fig.9 Calculation / Experiment ratio vs gap width and source position.

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