

## Measurement of Neutron Flux Distribution of STACY Heterogeneous Core by Position Sensitive Proportional Counter

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Measurement of neutron flux distribution of the Static Critical Experiment Facility (STACY) heterogeneous core in the Nuclear Fuel Cycle Safety Research Facility (NUCEF) in Japan Atomic Energy Research Institute (JAERI) by a position sensitive proportional counter (PSPC) was performed. As a result of measurement, the neutron flux distribution data with good statistical precision in critical and subcritical state of the STACY was obtained by the PSPC. The position precision of the PSPC is found to be less than  $\pm 1.3$ cm from the results of position calibration measurement. And the neutron flux distribution at the location of PSPC was calculated by using the continuous energy Monte Carlo code MCNP. The difference between calculation result and measurement result was within 11% in the range from half height of critical solution level to height of critical solution level. The calculation result was in good agreement with the measurement result with respect to the shape of neutron flux distribution.

**KEYWORDS: position sensitive proportional counter, neutron flux distribution, STACY, MCNP**

### 1. Introduction

In general, measurement of neutron flux distribution is performed by using scan method that a counter is moved many points and measured at each point, or activation method. These methods have a disadvantage that measurement of neutron flux distribution takes a lot of time (e.g., about one hour for scan method, or about five hours for activation method). In contrast, use of a position sensitive proportional counter (PSPC) makes it possible to shorten measurement time for neutron flux distribution considerably than that of these conventional methods. Moreover, while devices and manipulations to move a counter are required in the scan method, these are not required in measurement by a PSPC. Thus, measurement of neutron flux distribution can be performed easily by using a PSPC rather than by using the conventional methods.

The counting gas of the PSPC that we used is He-3. The PSPC basically has the similar structure of an ordinary He-3 proportional counter. Unlike ordinary He-3 proportional counters, however, output signals of the PSPC can be read from both ends of the anode wire of the counter. The relative detection position ( $X$ ) can be obtained by using the charge from one end of anode wire ( $Q_A$ ) and the charge from the other end ( $Q_B$ ) as follows<sup>1)</sup>.

$$X \propto \frac{Q_A}{Q_A + Q_B}$$

We have measured neutron flux distribution of the Static Experiment Criticality Facility (STACY) heterogeneous core in the Nuclear Fuel Cycle Safety Research Facility (NUCEF) in Japan Atomic Energy Research Institute (JAERI) by the PSPC. Also, we calculated the neutron flux distribution at the location of the PSPC by using the continuous energy Monte Carlo code MCNP<sup>2)</sup> with JENDL-3.2 library<sup>3)</sup> and the result of calculation was compared with the measurement results.

### 2. Experiment

#### 2.1 The PSPC and its measurement system

The PSPC's outer diameter, length and nominal active length are 2.54cm, 155.9cm and 142.2cm, respectively. The PSPC was made by Reuter-Stokes Incorporated. The PSPC's filling gas and filling pressure are He-3 and 0.2 atm, respectively. An applied voltage was set to 1000V. The block diagram of the PSPC is shown in Figure 1. The system showed in Figure 1 is a product of Laboratory Equipment

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Corporation. In Figure 1, List ADPs input output signal of ADC, and send EVENT signal and the output signal of ADC to the List Control. The List Control checks EVENT signals from the List ADPs. When EVENT signals from List ADPs are coincident within specified coincident time, the List Control sends output of ADCs to the List Memory. The List Control's coincidence time was set to 5μsec. Data stored in the List Memory are transferred to PC via Ethernet. By this measurement system, signals are recorded only when they are detected coincidentally from both ends of the anode wire of the PSPC.

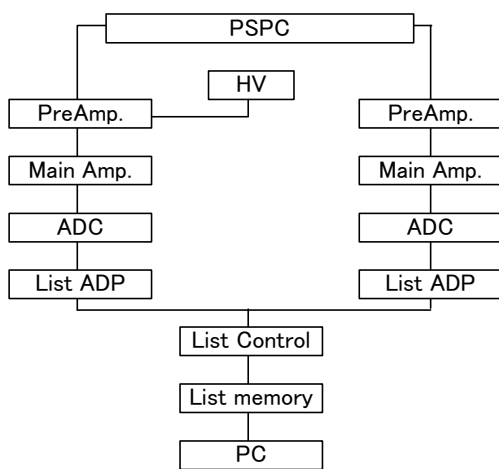


Fig.1 Block diagram of the PSPC measurement system

## 2.2 Position calibration measurement of the PSPC

A position calibration measurement of the PSPC was carried out by a method using a Cf-252 source and a cadmium collimator with a slit of 1cm width that covered the PSPC, and moving them every 5cm or 10cm along the PSPC and measuring each position. A measurement data is divided into counts per specified resolution (channel) by using data processing programs. Figure 2 shows the measurement results of the relationship between channel and position when resolution is 250 channels. In Figure 2, the relationship between the channel  $x$  and the position  $y$ (cm) is calculated as

$$y = -9.469e - 6x^3 + 9.473e - 3x^2 - 3.602x + 5.701e + 2$$

by using the least square method for fitting a cubic equation. The dashed lines of Figure 2 indicate confidence interval of the fitted line. The position precision of each channel was calculated as less than  $\pm 1.3$ cm from fitting result of Figure 2.

## 2.3 STACY heterogeneous core

STACY heterogeneous core composed of 5wt%

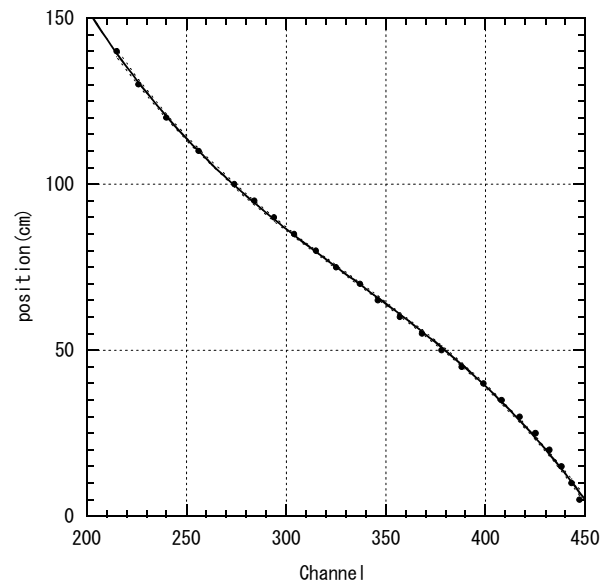


Fig.2 Relationship between channel and position of the PSPC from measurement of calibration. Dashed lines are confidence interval of the fitted line

enriched LWR type fuel rod array immersed in 6wt% enriched uranyl nitrate solution in a cylindrical tank. The cylindrical core tank is made of stainless steel, and the inner diameter is 59.0cm and the outer diameter is 59.6cm. Diameter of each fuel pin is 0.95cm. Number of the fuel pin was 221, and the square pitch was 2.1cm. Uranium concentration of uranyl nitrate solution was ranged from about 50g/L to 210g/L when measurements by the PSPC were carried out. On the bottom, side and top, there was a thick water reflector in reflector pool when water reflected experiment was performed.

## 2.4 Measurement condition

The PSPC was set vertically at near the STACY core tank. Figure 3 shows relationship between location of the PSPC and the STACY core tank. As shown in Figure 3, the distance between the core tank surface and the center of the PSPC was 9cm. The data measured by the PSPC was divided into 250 channels by using the data processing programs.

Table 1 shows the uranyl nitrate solution characteristics at the measurement of the PSPC that presented in this paper. This experiment was performed with water reflected. Table 2 shows measurement conditions of the PSPC.

Table 1 Uranyl nitrate solution characteristics

Uranium concentration (g/L)	51.7
Acidity (mol/L)	2.54
Density (g/cm <sup>3</sup> )	1.151

Table 2 Measurement conditions of the PSPC

Step	Solution height (cm)	Reactivity (\$)	Counting time (sec)
3	60.09	-0.99	600
4	62.50	-0.50	600
5	63.54	-0.29	1800
6	64.70	0.0	600

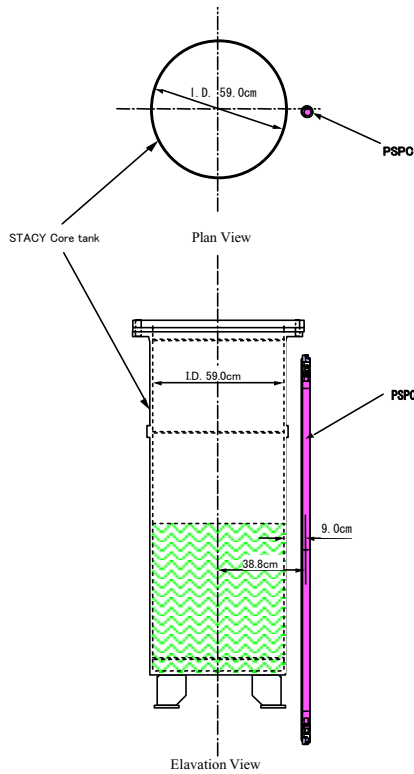


Fig. 3 Location of the STACY core tank and the PSPC

### 3. Calculation

To compare with the measurement results of the PSPC, a calculation of neutron flux distribution at the location of the PSPC was carried out by using the continuous energy Monte Carlo code MCNP 4C with JENDL-3.2 library.

Table 3 shows calculation condition of MCNP. Figure 4 shows calculation model of MCNP.

Table 3 MCNP calculation condition

Number of history per cycle	10000
Number of skip cycle	50
Number of total cycle	5050

As shown in Figure 4, a tally used was F4 tally (track length) that was set on cells that has the same location and volume as the PSPC.

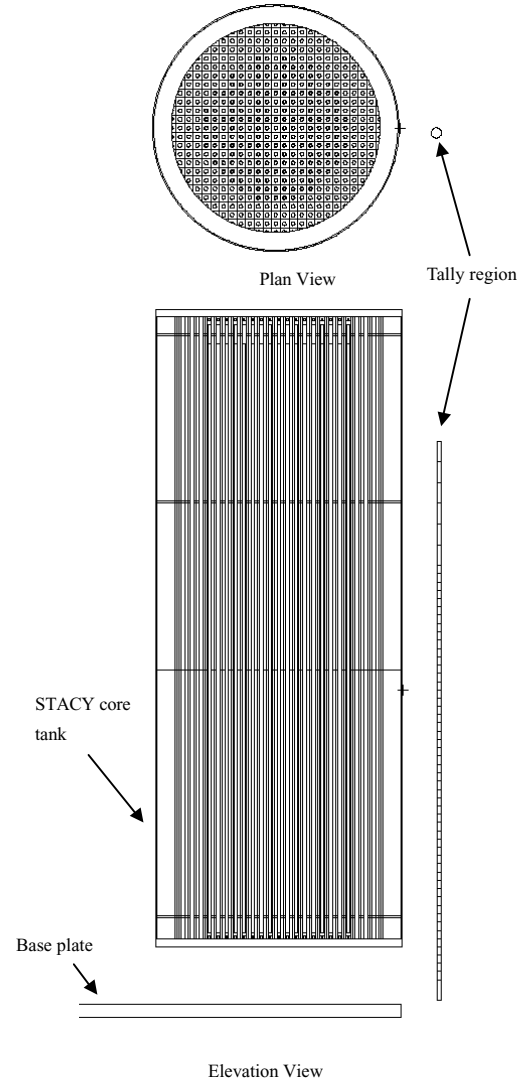


Fig.4 Calculation model of the STACY core tank and the PSPC for MCNP.

### 4. Results

Figure 5 shows neutron flux distributions of the STACY heterogeneous core measured by the PSPC. Note that the measurement result in step 5 is reduced to counts per 600 seconds. As shown in Figure 5, neutron flux distributions of the STACY were obtained when the STACY was in both critical and subcritical state. As seen in Figure 5, more than 10000 counts were obtained by 600 seconds' measurement in the almost active region of the PSPC.

Figure 6 shows comparison between measurement result of the PSPC and calculation result of MCNP in critical state. Statistical errors of each tallies of MCNP calculation result are less than 5.6%.

The difference between calculation result and measurement result was within 11% in the range from half height of critical solution level to height of critical solution level. However, the maximum difference was 59% at the other range.

## 5. Discussion

As seen in Figure 5, it is found that a neutron flux distribution with good statistical precision can be obtained by measurement of 600 seconds using the PSPC at the STACY.

In Figure 5, when reactivity was more than  $-0.5\%$ , it is found that neutron flux distributions were similar to the distribution in critical state. On the other hand, when reactivity was about  $-1.0\%$ , the distribution was different from the distribution in critical state since influence of the start up neutron source was large.

The neutron flux distribution that was calculated by MCNP differed from the measurement result about 59% at maximum. However, as shown in Figure 6, the calculation result was in good agreement with the measurement result with respect to their shapes of neutron flux distribution.

## 6. Conclusion

We have measured neutron flux distribution of the STACY heterogeneous core by the PSPC. As a result of measurement, the neutron flux distribution data in critical and subcritical state of the STACY heterogeneous core were obtained by the PSPC. Because counts at almost active region of the PSPC were more than 10000 with measurement in 600 seconds, the measured neutron flux distributions have good statistical precision.

The position precision of the PSPC is found to be less than  $\pm 1.3\text{cm}$  from the results of position calibration.

The calculated neutron flux distribution by MCNP at the location of the PSPC was in agreement with measurement data within 11% in the range from half height of critical solution level to height of critical solution level, although the maximum difference was 59% at the other range. The calculated distribution data was in good agreement with the measurement one with respect to their shapes of neutron flux distribution.

As a future work, we are planning to prepare a

PSPC of lower sensitivity for measurement in high neutron flux region. By this PSPC, measurement of neutron flux distribution can be performed at closer position of core tank or in higher power operation.

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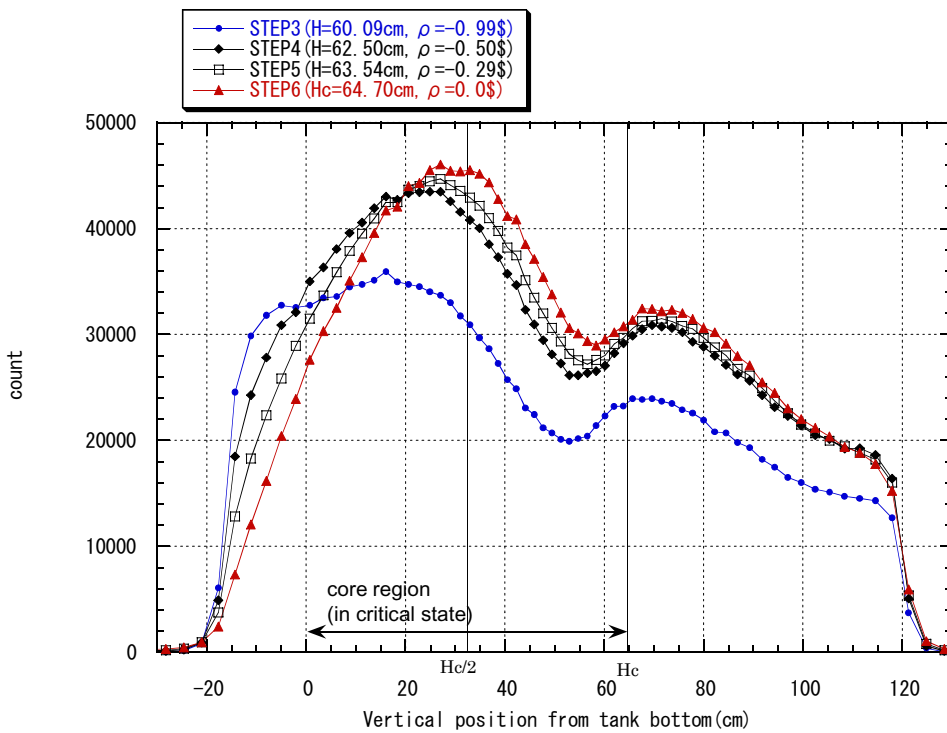


Fig. 5 Results of the measurement of neutron flux distribution by the PSPC

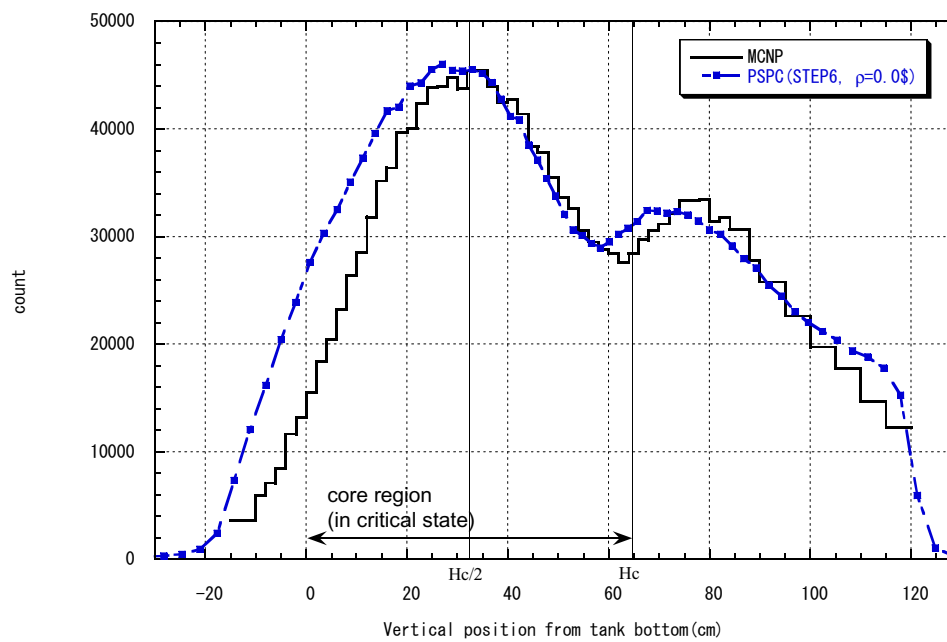


Fig. 6 Comparison between MCNP calculation result and the PSPC measurement result