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Compensation for Extremely Low Count Rate of PCS Neutron Monitoring System

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1. Introduction

The failed fuel detection in research reactors can be usually performed by the measurement of delayed neutrons in the primary cooling system (PCS). The count rate of the PCS neutron monitoring system (PNMS) depends on the detector's sensitivity as well as the installed situation. The accuracy and reliability of this count rate influence not only the reactor operation but also the determination of PNMS trip set point. However, the real surroundings of the installed PNMS are more likely different from those as planned due to the site conditions such as GA modification. For instance, given that detectors are installed far from the target point (PCS pipe), we need to come up with the idea of adequate compensation. Herein, the actual approach for the count rate of the PNMS is discussed.

2. Problem in Actual Count Rate of PNMS

The PNMS count rate is a reactor trip parameter as a safety system. It has the function of providing a reliable count rate to help the reactor drive into a safe shutdown when any damage to the nuclear fuel happens over the limit. Since the count rate must be accurate, thus its sensitivity with location should be confirmed before in-site installation.

2.1 PNMS detector (BF_3 Counter) Installation

Based on the manufacturer's data, the normal count rate is estimated around 200 cps (count per sec). The time taken for the PCS flow to pass by, the reactivity rate of the nuclear fission in the PCS, and the delayed neutron source are also considered in the count rate. After that, given that the maximum surface contamination of nuclear fuel is 3.8% of the tolerance, we can expect the count rate to reach approximately 8 cps. The count rate at the site was observed to be 1.5, which is much lower than originally thought.

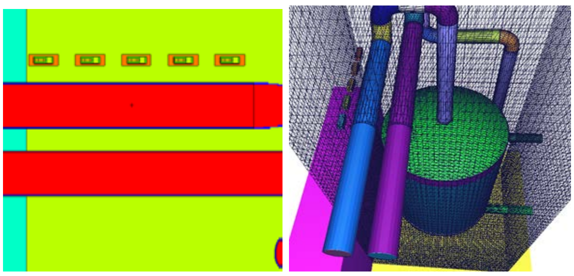


Fig. 1. Installed situation of PNMS in site

It can be compared with a certain previous case, which represents 100~1,000 cps during normal reactor operation, and also indicates that 1~2 cps is an extremely low level. To find the reason for such a low count rate, the arrangement of the PNM detector, BF_3 counter, is investigated, as shown in Fig. 1. The detectors were first located within a close perimeter of 30 cm off the PCS 14' line, their change in place is almost 10 cm away from the PCS centerline. Unfortunately, the decay tank lies under the PCS room where the detectors are installed, and the floor is made of gratings, and thus it was impossible to build the detectors' supports on the ground owing to seismic requirements.

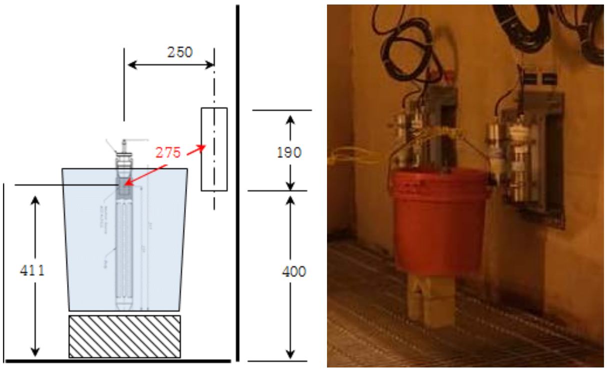
2.2 Measured count rate in changed detector location

The change in detector location was on the wall of the PCS room being distant from the neutron source. Let us consider the neutron source from both the PCS line and the decay tank. That would be the photo and delayed neutrons. First, the effects of photo neutrons by N-16 are negligible since nothing but the yielded neutrons by high energy gamma are considered, which have an energy level of more than the threshold of 2.2 MeV. The second factor is that the delayed neutron can be estimated given that all fission products in the core are flowed into the PCS line. For the delayed neutrons, all components such as the half-life, decay constant, reactivity rate per fission products considered, and the expected count rate were obtained at 108 cps when the detector efficiency is 0.83 cps/nv, as shown in Table 1.

Table 1. Comparison of PNMS count rate

	Reference	Original location	Changed location
Thermal neutron flux (#/cm^2-sec)	168	130	250
Detector Efficiency (cps/nv)	1.5	0.83[1)]	0.83[1)]
Count rate (cps)	252	108	207

When the full power operation is assumed, the expected count rate in the original/changed location was measured too small to establish the set point. Thus, we conducted an experiment, as illustrated in Fig. 2, to make sure that real efficiency of the BF_3 counter is proper and how much the count rate should be raised. There are neutrons installed in the bucket, which is distant from the three channels of the PNMS detector on the wall. In response to the gradually increased distance, the trend of count rate was measured piecewise.



Detector: 60 (ϕ) x 190 (L) Distance from the detector to the center of source: 280

Fig. 2. Experimentally measured count rate at distance

3. Compensation for weak PNMS count rate

The displayed rate-meter in PNMS decreased from 1.5 to 0.2. The reason why such an extremely low level was found is there is a very initial core in which we hardly expect the fission products to lead to more N-16. The other clue is, obviously, the less sensitivity of the detectors and larger distance from the source. The easiest way to increase the count rate would be achieved by adjusting the HV gain of electronics rate-meter, but this is not recommended because it may cause a distortion of the inherent HV-count characteristics, causing a bad performance.

After a long discussion, we scaled up the span that was considered to indicate 1 to 100,000 cps. With five decades of measuring range unchanged, we shifted the available range to 0.01 to 1,000 cps by a firmware update. It is fortunate that no further software verification was required because the field that we adjusted belongs to the configuration data. It did not affect the system performance as long as the modified data was not beyond the available measurement range. The count rate was verified after the adjustment, and showed a little fluctuation within the boundary of 20 to 50 cps, which we can consider the set point of the PNMS.

4. Conclusions

Thus far, the issue of the count rate in the PNMS has been dealt with, and a simple approach for the count rate compensation was suggested based on the experiment. The introduced modification of signal processing electronics enables operators to avoid relocating the detectors and changing the detectors themselves due to a lack of efficiency. However, the change of measuring range still has a problem in that the measured value lies around a very low range, and hence we need to increase the stability of that range together with this approach.

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