Performance Evaluation of Vanadium-Platinum In-core Detectors at Halden Reactor

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1. Introduction

The depletion and dynamic test results for vanadium–platinum hybrid Self-Powered Neutron Detector (SPND) are described. The test detector is a prototype of the MAPSSEL detector developed by Korea Electric Power Research Institute (KEPRI)/WH and has been installed in Halden reactor core. The purpose of the test is to confirm the performance of the detector is consistent with the predicted design calculation. The test results show that the detector performance is acceptable for core monitoring application.

2. Principle of vanadium–platinum detector

The signal production mechanism in an V detector emitter relies primarily on beta particles resulting from neutron absorptions in V^{51} isotope to produce an electric current. The V SPND has longer lifetime (typically more than 12 years) compared with Rh (not more than three operating cycles) being used in KSNP. The cost associated with the periodic replacement of the Rh detector is the primary driving force for the development of a longer-lived V-Pt design. But the longer time-delay of the V emitter (325 sec) than that of Rh (175 sec) requires a special consideration on dynamic compensation to prevent the loss in operation margin.

The Pt detector signal relies primarily on Compton and Photoelectric electron scattering.[1] In principle, Pt detector can remain in use indefinitely since signal output from the Pt will be a function of the local gamma radiation population but has large uncertainty. The main purpose of the installation of the Pt detector is to check the integrity of the pair V detector and to be calibrated by V detector signal. An added benefit to the application of a gamma sensitive detector is that a large part of the signal is prompt responding. This property allows the signals from the Pt detectors can be used to the reactor protection system in the future.

3. Description on the experiment

The irradiation test of the vanadium-platinum detectors is performed in a test assembly installed in the Halden BWR core. The configuration of the SPNDs in the test assembly is shown in the table below.

Identification	Description
ND-6	Vanadium - Emitter length 100 mm - Emitter diameter = 2.0 mm
ND-7	Vanadium - Emitter length 317.5 mm - Emitter diameter = 1.2 mm
ND-8	Platinum - Emitter length 317.5 mm - Emitter diameter = 1.2 mm

ND6 is previously installed V detector delivered by Studsvik Instrument. ND-7 and ND-8 are MAPSSEL vanadium and platinum detector, respectively. As can be seen from Fig. 2, the time response of the MAPSSEL vanadium (ND-7) is similar to the time response of another vanadium(ND-6). The MAPSSEL platinum (ND-8) at the start of the reactor shows unexpected slow response due to a relay card problem in transmission line which will be investigated further.

4. Estimation of current amplitude

The thermal neutron flux at the level of ND-6 is about $6x10^{13}$ n/(cm^2 s). Assuming an SPND sensitivity of $2x10^{-21}$A/(n/cm^2 s), we can find the expected current of 120 nA in agreement with the observation. Based on the expected profile, a flux level of $5.5x10^{13}$ n/(cm^2 s) can be expected for ND-7 and ND-8.

Assuming a sensitivity proportional to the emitter diameter, the sensitivity of ND-7 should be reduced by the factor 1.2/2, so that the combined effect of larger length and lower diameter would be an increase in sensitivity (relative to ND-6) of 1.9. This is correspond to a sensitivity of $3.8x10^{-21}$ A/(n/cm^2 s), leading to an expected current of 209 nA. The observed current is about 240 nA. In view of all the uncertainties and approximations, the agreement is acceptable. To investigate Pt detector current, we can go back to the results obtained by Allan[2], where gamma sensitivities for different platinum SPNDs are reported. For a solid platinum emitter of 1.2mm, the total sensitivity is $4.73x10^{-25}$ A/m/(n m^{-2} s). With this sensitivity, the expected current is 83 nA whereas the measured current is 95 nA. A more precise estimation is being performed based on detailed sensitivity calculation with Monte Carlo method.

During the irradiation, some reactor scrams occurred and the dynamic performance of each detector are analyzed. Fig. 3 and 4 show the measured, simulated and H_∞ filter[3] compensated signals during a scram. The simulated responses almost exactly follow the measured signal for both of V and Pt which demonstrates the applicability of the dynamic model. The compensated signals with H_∞ filter show perfect agreement with reference power trajectory.

5. Conclusion

The irradiation and dynamic experiment of the vanadium-platinum detectors is performed The test result shows the MAPSSEL SPND behaves as expected. The applicability is also demonstrated for the dynamic model of each detectors and H_∞ filter for dynamic compensation of delayed signal. The developed dynamic model can be implemented in core monitoring method using V-Pt detectors.

References

[1] R.B. Shields, "A Platinum In-Core Flux Detector," IEEE transactions on Nuclear Science, February 1973, NS-20, 603-608.

[2] C.J. Allan, "Response Characteristics of Self-Powered Flux Detectors in CANDU Reactors," International Symposium on Nuclear Power Plant Control and Instrumentation, 1978, Cannes, France

[3] M. G. Park et al., "H_∞ Filtering for Dynamic Compensation of Self-Powered Neutron Detectors - A Linear Matrix Inequality Based Method -," Annals of Nuclear Energy, 1999, 26, 1669-1682.

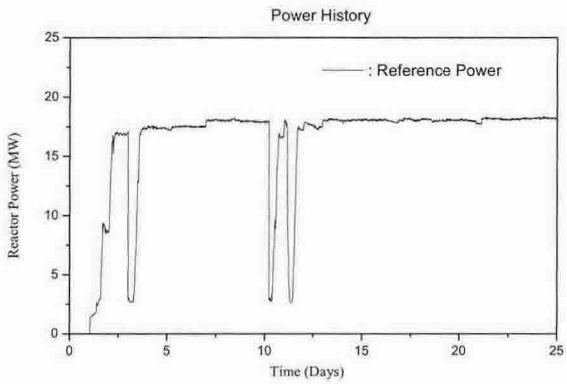

Fig. 1 Power history of Halden Reactor

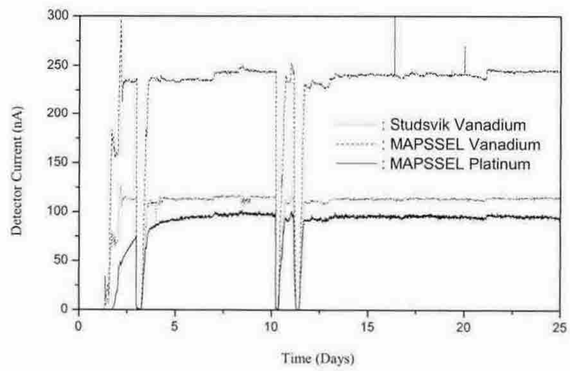

Fig. 2 Measured currents of detectors

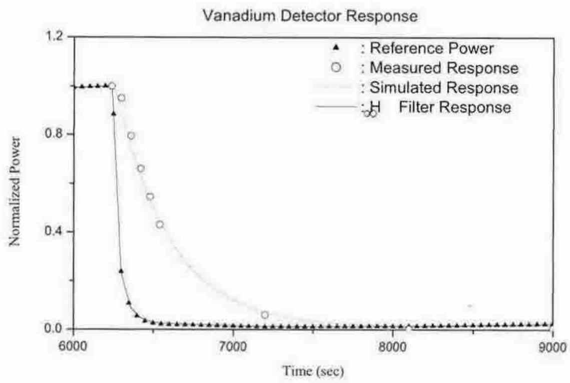

Fig. 3 Response of V detector during scram

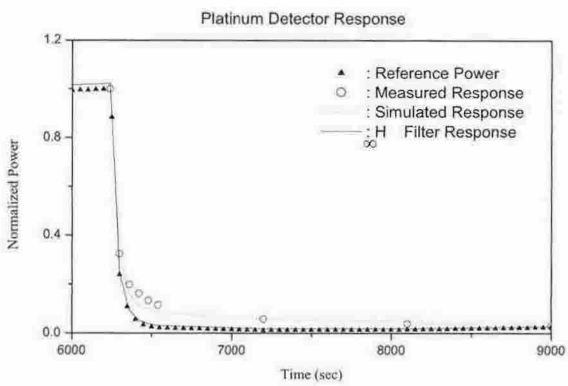

Fig. 4 Response of Pt detector during scram

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