REPLACEMENT OF HANARO NEUTRON DETECTOR

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ABSTRACT

In 1994, HANARO (High-flux Advanced Neutron Application Reactor) Neutron Detectors, which are a Wide-range Fission Chamber type developed by Gamma-Metrics, were installed at the HANARO Reactor Protection System (RPS) and Reactor Regulating System (RRS). HANARO selected a wide-range Fission Chamber, which is better than an Ionization Chamber in terms of mechanical performance. An Ionization Chamber uses a guide tube in underwater. In addition, an Ionization Chamber needs a shutter mechanism for correcting the detector. However, a wide-range Fission Chamber is not necessary for the guide tube and shutter mechanism. HANARO Neutron Detectors are used for generating an electrical signal for operating HANARO. We found an abnormal electrical signal in 2004, which considerably affected the HANARO RPS and RRS. Therefore, we checked the electrical signal and electrical insulation resistance of the HANARO neutron detectors. Consequently, because the electrical insulation resistance decreased, the HANARO neutron detectors were operating under abnormal conditions. Therefore we changed the neutron detectors. This paper describes the procedure and results from changing the neutron detectors.

1. Introduction

The HANARO neutron detectors are an important component in the operation of the HANARO as parts of the RPS and RRS. The RRS uses the power control of reactor and RPS uses the trip of reactor. The wide-range fission chamber neutron detectors were mounted in 1994 and supplied from the Gamma-Metrics. HANARO choose the wide-range fission chamber type because the wide-range fission chamber is better than ionization chamber at mechanical performance. Ionization chamber not able to be directly installed into the water, therefore the guide tube is absolutely necessary. And Ionization chamber needs the shutter mechanism for control of neutron flux. That is control the neutron flux for correction of detector. Consequently, very complex structures should be installed in reactor pool for using the ionization chamber. Wide-range fission chamber type is not necessary the guide tube and shutter mechanism why that is installed directly into the reactor pool [1]. In 2004, we found the abnormal oscillation that is the linear output and log scale output of neutron detector display in reactor control room. In addition, RRS trip was generated because of the abnormal oscillation. Therefore, we checked the performance of neutron detector through various experiments and then replacement for all channels of RPS and RRS from 2008 to 2012.

2. Neutron Detector

2.1 Principle of wide-range fission chamber and compose

Principle of wide-range fission chamber is as follows;

Neutrons came into being in the fission chamber to produce a fission product and uranium molecule. Fission product is allowed to ionize the gas (90% argon, 10% nitrogen) filled in the chamber, ionized electrons of gathered anode generates a current pulses. So number of current pulses is proportional to the number of neutrons that means output of neutron flux. That is the operating principle of unguarded fission chamber type which is commonly used. HANARO uses the guarded fission chamber type neutron detector. The guarded fission chamber type is composed of the region of filled gas and two coaxial cables. The region of filled gas (95% argon, 5% nitrogen) was coated by U-235 and coaxial cable was located between the region of gas. Created electrical signal by neutrons is sent to signal amplifier. The wide range log scale signal is sent by form of pulse in coaxial cable of high voltage, DC current is sent through the signal return coaxial cable that is proportional to neutron flux and means a linear output of neutron flux. Wide-range Neutron Measurement System of HANARO can be measuring the neuron flux in 10 decade from 10^{-8}% Full Power to 150 % Full Power at log scale and 0% Full Power to 150 % Full Power at linear scale. Table 1 shown specification of fission chamber for HANARO. Shown table 1, operating voltage plateau is 200~900 V, HANARO uses the 870V.

2.2 Consists of neutron detector assembly

Neutron measurement system is composing the wide-range fission chamber, signal amplifier, signal processer, cable, and aluminum conduit. In response to the signal

Compartment	Item	Property
Mechanical	Diameter	3 ± 1/16 Inches
	Overall Length	15 7/8 ± 3/16 Inches
	Approximate Sensitive Length	9 1/4 Inches
	Net Weight	3.0 Pounds
Materials	Element Body	Aluminum
	Electrodes	Aluminum
	Insulation	High Purity Alumina Ceramic
	Neutron Sensitive Material :	
	- Content - Thickness - Total Quantity of U-235	U_3O_8 Enriched to ≥ 90% in U-235 0.6 ㎎/㎠ 0.72 grams
	Gas Filling	95% Argon – 5% Nitrogen Mixture
	Gas Pressure	76 ㎝ of Hg
Max. Ratings	Voltage Between Electrodes	1000 volts
	Temperature	420 ℉
	External Pressure	180 Pounds/Inch^2
	Thermal Neutron Flux	10^{11} nv
Typical Operation	Operating Voltage	300 volts
	Operating Voltage Plateau	200 ~ 900 volts
	Thermal Neutron Flux Range	3.3 ~ 3.3 X 10^5 nv
	Sensitivity	0.3 cps/nv
	Thermal Neutron Sensitivity	9.0 X 10^{-14} Amps/nv (min)
	Gamma Sensitivity	6.0 X 10^{-11} Amps/R/HR (max)

Tab 1. Specification of fission chamber

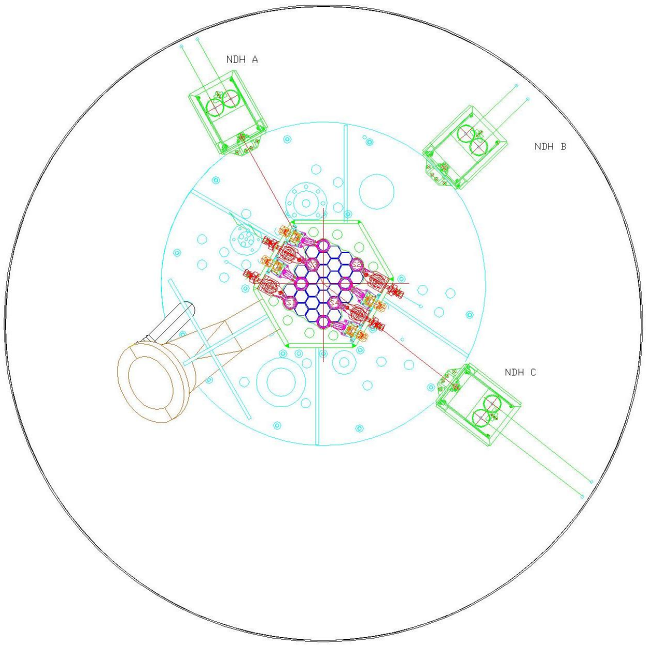

Fig 1. Top view of Neutron Detector Housing

of neutron flux from signal amplifier, signal processor generates a signal of reactor emergency stop to the abnormal state of the reactor and an important variable of reactor power control algorithm. Cable composed the organic-insulated and mineral-insulated cable and that is installed in aluminum conduit. Two fission chambers are installed in one of the neutron detector housing. Each fission chamber is used for RPS and RRS which is composed of a three channel. Therefore, the neutron detector housing needs a three sets in HANARO. Neutron detector housings are fixed symmetrically on the outer wall of the reflector tank. The round basket is located each neutron detector housing for installing the fission chamber as shown in figure 1. Location of neutron detector housing was selected where it is possible to reduce to the effect of the vertical and horizontal experimental holes in reflector tank that surround the reactor core [2].

3. Replacement of Neutron Detector

From 2004, neutron detector system of RPS and RRS are generating the abnormal signal. Considering the life of the detector 8 to 10 years, we performed a precision inspection because the abnormal signal is a need to determine clearly whether the aging phenomenon or simple failure. We checked the power supply status, normal operating of discriminator and band pass filter inside the panel and measured the insulation resistance. Aluminum conduit of not good insulation is implementing a vacuum evacuation and N_2 purging [3]. After the vacuum evacuation and N_2 purging, replaced the neutron detector regarding the channel of not good insulation resistance. And we checked the Time Domain Reflectrometer(TDR) before and after vacuum evacuation and N_2 purging because of checking the damage and electrical short of cable. Vacuum evacuation and N_2 purging for preventing dielectric breakdown in the cable removed the moisture using nitrogen gas and vacuum pumping inside the aluminum conduit.

SIG to coax	HV to coax	pin to pin	Shield to Ground	
4.5×10^9 Ω	4.0×10^9 Ω	4.4×10^9 Ω	1.0×10^6 Ω	pre- evacuation
4.5×10^9 Ω	3.9×10^9 Ω	4.5×10^9 Ω	1.5×10^6 Ω	post- evacuation

Tab 2. Insulation resistance of RPS B channel

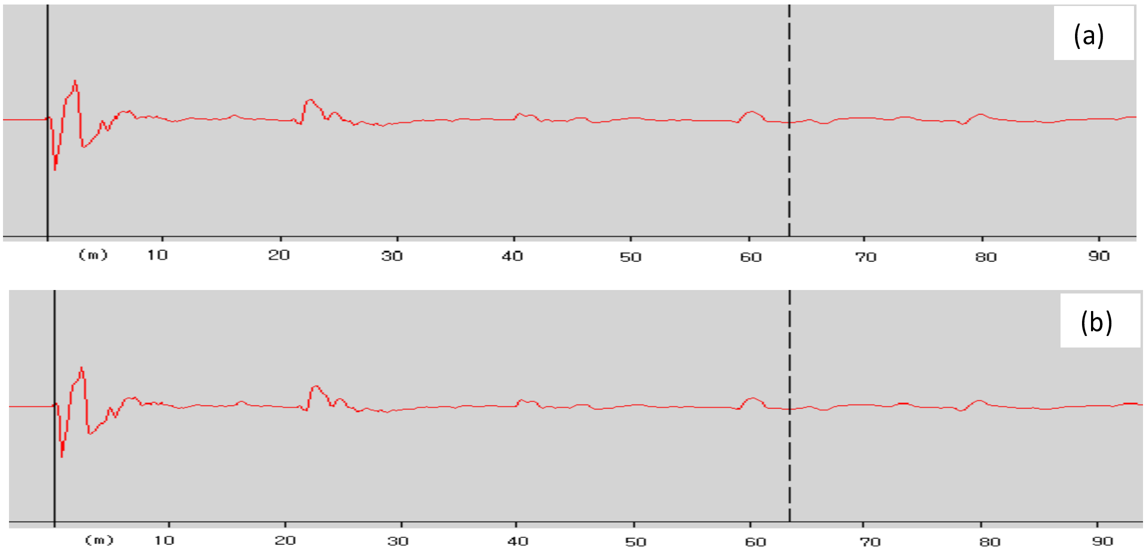

Fig 2. (a) TDR plot of HV(log scale signal line) and (b) TDR plot of SIG(linear signal line)

Table 2 and Figure 2 are indicating the data of insulation resistance and TDR of the RPS B channel in 2006. Shown the table 2, Insulation resistance of shield to ground is very low after post-evacuation. However, Insulation resistance (1.5×10^6 Ω) is accepting value by manufacturer. Signal line is composing the two signals as SIG and HV. SIG is generating a linear output of neutron flux and HV is making the log scale output of neutron flux. RPS B channel was generating the intermittent abnormal signal. We were conducting the vacuum evacuation and N_2 purging, particular problem has not been found. Nevertheless we were replacing the neutron detector in 2008 as preventive maintenance. Other channels of RRS and RPS also run the same tests. It was replaced respectively in 2010 and 2012 as same reason. Result of the measured insulation resistance of the pre-installation and post-installation in the reactor pool, insulation resistance is reduced after installation in the reactor pool. The reason is that a current is generated inside the detector by neutrons in reactor core. Leak test confirmed that the leakage does not occur after a lapse of 15 minutes to connect the aluminum conduit and fission chamber by injecting at a pressure of about 105 kPa nitrogen gas into the aluminum conduit inside. As a result, we have found that the water in reactor pool is not penetrating the neutron detector system.

4. Conclusions

We found an abnormal signal from a neutron detector in 2004 and confirmed the operation state of the neutron detector assembly. No special problems were discovered through a performance tests (vacuum evacuation, N_2 purging, TDR test, leak test and checking the Insulation resistance) of the neutron detector system, however we replaced the neutron detector of all RPS and RRS channels from 2008 to 2012 as preventive maintenance. In particular, the neutron detector of the RPS C channel was successfully checked and installed without the help of the manufacturer. By replacing the neutron detector system for all channels, it is possible to expect the stable operation of HANARO.

5. References

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[3] GAMMA-METRICS, “Instruction Manual. 170, Rev.1 –Neutron Flux Monitor for KAERI”, KMRR Site