Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Development of Detection Algorithms Using Delayed Neutrons in Coolant for Failed Fuel in a Liquid Metal Reactor

S.H. Seong, S. Hur, Jae-Chang Park and S.O. Kim
Korea Atomic Energy Research Institute
shseong@kaeri.re.kr

1. Introduction

When the fuel assemblies in a liquid metal reactor are failed, the safety and operability of the reactor will be threatened. The early detection for the failed fuel assembly during normal operation is an important issue for a liquid metal reactor. If a fuel assembly is failed, the precursors which can produce the delayed neutron by radioactive reactions are released into the primary coolant through the failed location. Those are confined in the fuel assemblies and are not released into primary coolant when the integrity of the fuel assembly is maintained. If the fuel assembly fails to maintain the integrity, then the precursors are dissolved in the primary coolant and circulate the primary heat transfer loop. Finally, the delayed neutrons are generated in the primary heat transfer loop. So, the existence of the delayed neutron in the primary coolant can give some information for the fuel assembly failure. [1]

For detecting the delayed neutron in the coolant, the fission chamber in the primary coolant will be adopted among several measurement instruments and installed within the free space of the intermediate heat exchanger. The fission chamber is less sensitive to background noises such as the high energy gamma ray and alpha particles in the reactor or primary coolant and can be manufactured with small size. After measuring the delayed neutrons in the primary coolant, we can identify the failures of the fuel assembly in a liquid metal reactor if those levels are beyond the predefined thresholds which will be determined from the detailed plant design data later.

2. Characteristics of delayed neutron in a core

The delayed neutrons in a core have been born from the radioactive decay of fission fragments (precursors) generated from fission reactions. The representative nuclides of the precursors are Br-87, Br-88, I-137, I-138 and so on. For convenience of analysis, the delayed neutrons can be categorized into 6 groups by the decay constant of precursors. The half life of first group is more than 50 sec, it of the second group is about 20 sec and those of the other groups are less than 100 sec. The dominant characteristics of the delayed neutron in the primary coolant are governed by the 1, 2 groups of the delayed neutron, due to the relatively long life time. [2]

The delayed neutrons and the precursors are confined in the fuel assembly when the fuel is healthy. If some failures occur on the surface of the fuel assembly, the delayed neutrons and the precursors are released into the coolant. The release rate is dependent on the failure size and the pressure difference between the gas pressure in the fuel rods and the pressure of the primary coolant in the core. [3][4] The exact pressure difference is varied according to the operational conditions and the characteristics of the manufactured fuel assembly and will be determined after the detailed design of the fuel rod.

3. Characteristics of the Neutron Detectors [5][6]

The widely used neutron detectors are BF-3 counter and fission chamber. The BF-3 counter uses the reaction between the coated B-10 nuclide and the neutron.

B-10 +neutron -> Li-7 + alpha

According to the reaction between B-10 and neutron, the two energy peaks show at 2.31 and 2.97MeV. Fig.1 shows typical energy spectrum of BF-3 counter. Also, the BF-3 gas with highly enriched boron can be easily obtained and it shows high linearity of the detection. However, the level of energy peak is affected by the background high energy gamma-ray and electrical noises because the energy peaks are about a few MeV. So, the BF-3 counter is not adequate in the primary coolant which has high energy gamma and much noise.

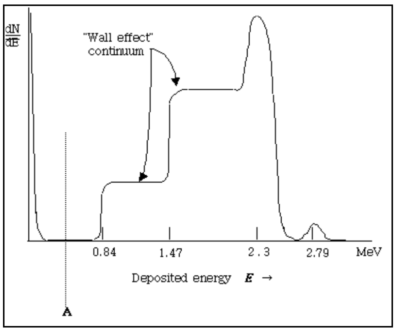

Fig. 1 Typical energy spectrum of BF-3 counter

Secondly, the fission chamber detector can be used for measuring the delayed neutrons in the coolant. The detector measures the delayed neutron, which are based on the small fission reaction in the detector.

U-235+neutron -> fission fragment + 165MeV

The U-235 element can be changed to U-239 according to the energy of the target neutron. Since the energy peak is so high (~167MeV), it can be used in the high energy gamma-ray background and has high efficiency to detect the neutrons with small size. Also, all of the fission fragments are confined in the detector because the mass numbers of fission fragments are very large. Fig.2 shows typical energy spectrum of fission chamber. So, we will use the fission chamber to detect the delayed neutron in the coolant from the failure of fuels in the core.

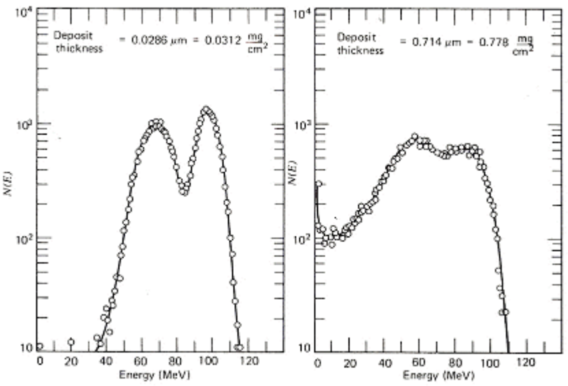

Fig. 2 Typical energy spectrum of fission chamber

4. Conclusions

The precursors are released through the failed part of the fuel assembly. If the precursors are once released into the primary coolant, those are circulating the primary loop. The precursors are decayed out through radiation reactions and detected in the fission chamber in the primary loop. The fission chambers can be installed in the intermediate heat exchanger (IHX). The detected density of the delayed neutron in the primary coolant is dependent on the precursors mixing in the coolant and the location of the failed fuel. The accurate numbers and the locations of the detectors have not been determined yet. Also, the threshold of the detection rate is not determined at present. Those are determined through the hydraulic mockup test of primary coolant and by consideration of the decay constants and the background in the primary coolant.

However, we assumed 4 detectors (fission chambers) are installed in each intermediate heat exchanger and the space between each detector is equi-distant in the IHX as shown Fig. 3.

Acknowledgements

This study has been carried out under the Nuclear R&D Program by MOST in Korea.

References

[1] CRBRP PSAR Chapter 7&8
[2] A.E. Walter and A.B. Reynolds, Fast Breeder Reactors, Pergamon Press (1981)
[3] M.S.Kim et al, Investigation of Possibility for Failed Fuel Detection by Using the Neutron Measurement in Primary Cooling Circuit of HANARO, KAERI/TR-1608/2000.
[4] Ayazuddin, et al, Fuel-Failure Detection System for Pakistan Research Reactor-1, Annals of Nuclear Energy, Vol 24, No. 15, pp 1213-1222 (1997)
[5] N. Tsoulfanidis, Measurement and Detection of Radiation, Hemisphere Publishing Co. (1983)
[6] G.F. Knoll, Radiation Detection and Measurements, John Willy & Sons Co. (1989)

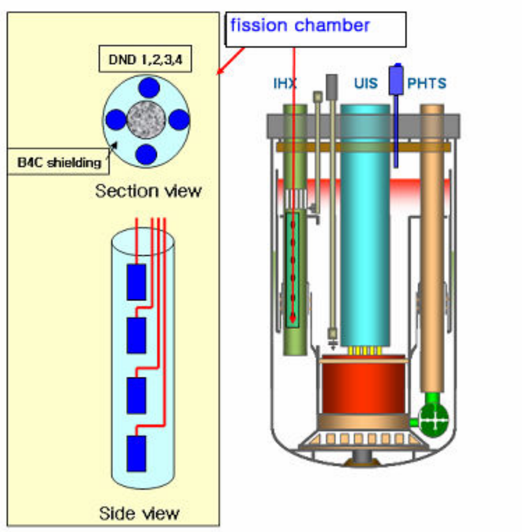

Fig. 3 Schematic location of the fission chambers