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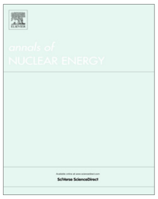

Delayed neutron measurements with a natural uranium fission product source in Fast Breeder Test Reactor

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ABSTRACT

An assessment of the sensitivity and localization capabilities of clad failure detection by Delayed Neutron Detection (DND) system in Fast Breeder Test Reactor at Kalpakkam has been done, by a series of delayed neutron measurements. Experimental simulation of failed fuel pin is done by considering a natural uranium fission product source in the form of special subassembly containing natural uranium pins, each having a large exposed area in the form of small holes. The measurements and analysis of delayed neutron signals with special subassembly in several selected locations are presented.

1. Introduction

Fast Breeder Test Reactor (FBTR) is a 40 MWt sodium cooled loop type reactor located in Kalpakkam with two primary sodium loops. Fuel for the reactor consists of (Pu,U)C, (Pu,U)O_2 subassemblies (Srinivasan et al., 2006). Each subassembly has 61 fuel pins. The reactor has been successfully operating with a large number of fuel assemblies experiencing burnup exceeding 155 GWd/t. Any fuel clad failure can have the consequences of contaminating primary circuit and cooling disturbances due to leaked fuel particles. Therefore, detection and localization of failures is very important. Clad failures generally have two phases (Jacobi, 1982): At first, they start leaking fission gases alone and do not release delayed neutron precursors, solid fission products or fuel. In the second phase, they start releasing Delayed Neutron (DN) precursors. It may take hours, days or even months before failures progress from gas leaking phase to DN release phase. In the DN phase, there is direct contact between fuel and sodium. Hence there are fair chances of solid fission product and fuel leak. The risk that Pu escapes from fuel pin when clad is breached brings about the requirement of continuous surveillance of fast reactors (Michaille and Berlin, 1982). Hence it is important not only to detect but also find the location of the failure early so that appropriate action is taken. There are many methods of localization. Delayed Neutron Detection (DND) with individual or sector sodium sampling, dry and wet sipping, cover gas tagging methods have commonly been employed(Jacobi, 1982). The sipping methods are considered time consuming and tagging methods expensive. DND with individual sodium sampling is one of the best methods. However this cannot be implemented in small loop reactors. FBTR has Gaseous Fission Product Detection (GFPD) system and DND system with sector primary sodium sampling (Sangodkar, 1982). Two DND blocks are provided, one on each primary loop and the signals are incorporated in the reactor scram circuit. The localization capabilities of DND system can be assessed and enhanced by calibration measurements of DN signals from a suitably chosen fission product source at various locations. This paper reports a series of such measurements of DN signal performed with a natural uranium alloy fission product source.

The core has three types of fuel assemblies, MK-I, MK-II and MOX. MK-I and MK-II are (Pu,U)C carbide fuel assemblies with Pu content of 70% and 55% respectively. MOX is (Pu,U)O_2 fuel with 44% Pu. Fission Product Source (FPS) is a special subassembly consisting of 19 stainless steel cladded natural Uranium–Nickel metal alloy pins surrounded by 42 dummy stainless steel pins as shown in Fig. 1. Clad of each natural U–Ni pin is perforated and has large exposed area in the form of 189 small holes of 2 mm diameter. This exposed area amounts to 5.94 cm^2. Fig. 2 gives the core configuration and the locations where the special subassembly was loaded viz., in the central (00,00) location, (02,04) and (02,10) locations in the second ring, (04,07) and (04,19) locations in the 4th ring and also two off central (02,08) , (04,04) locations.

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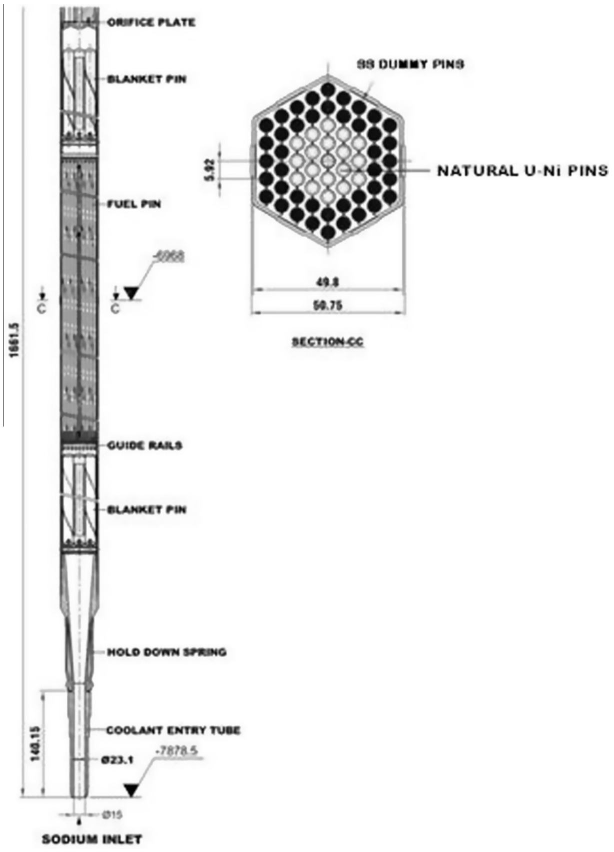

Fig. 1. Special DND subassembly containing 19 natural U–Ni pins.

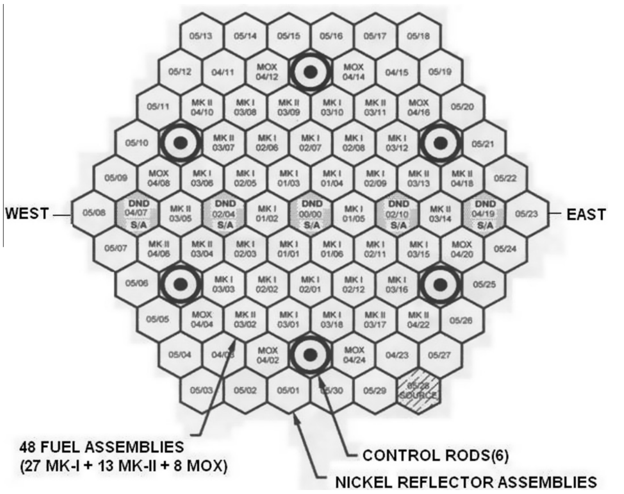

Fig. 2. FBTR Core Configuration with locations where FPS (special DND S/A) was loaded for DND measurements.

In Section 2, the description of the detector block is presented. In Section 3, the measurements carried out with the special assembly at various locations are described. Discussions and results are presented in Section 4.

2. Detector block

The DND system consists of two DND blocks, each positioned around a sodium pot connected in a bypass primary sodium loop across IHX shown schematically in Fig. 3. A sodium capacity of 5 L in this bypass line is viewed by six boron coated proportional counters for detection of delayed neutrons (Sangodkar, 1982). The transit time of sodium from the core to the detector is about 33 s. The detector block also shown in Fig. 3 contains a lead shield for attenuating gammas and permali wood for moderating the neutrons. Cadmium lining around the detector block helps in reducing the stray neutron background on the detectors. Boron coated counters have a sensitivity of 8 cps per unit neutron flux. Two counters are connected in parallel to an instrument channel so that the six counters on each loop form three redundant channels.

3. Delayed neutron measurements

3.1. Background

Background neutron signal is due to sources like ambient neutron flux, streaming of neutrons in sodium, fission in tramp uranium present in sodium and plutonium contamination sticking to the surface of the fuel pins and photoneutron production. The

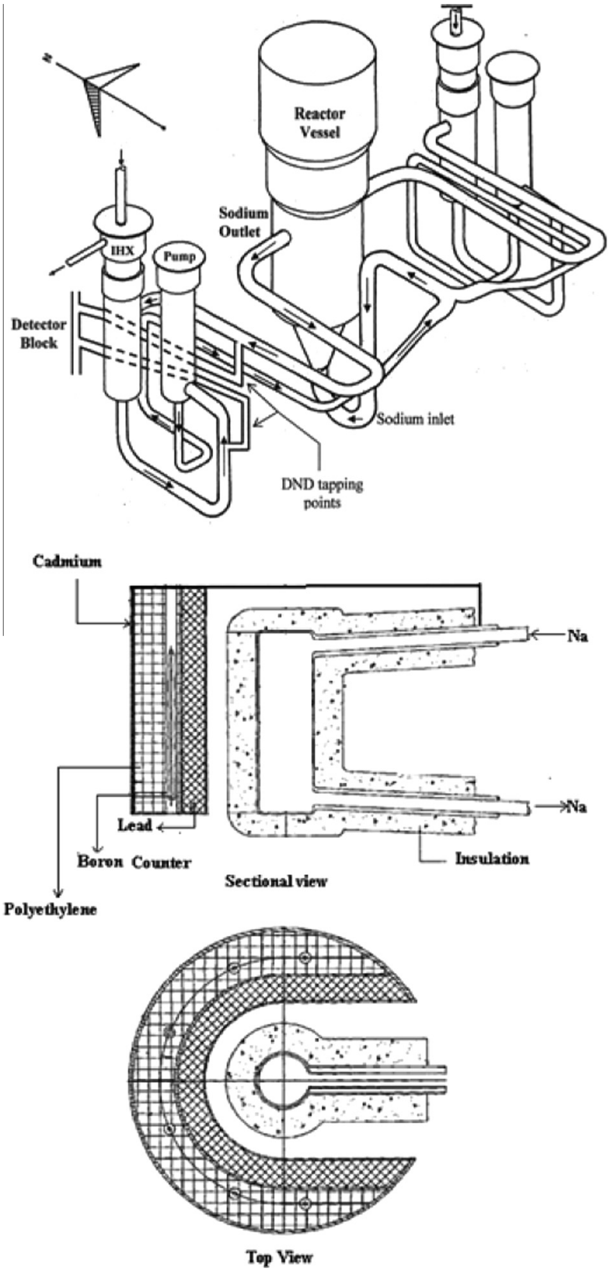

Fig. 3. Primary sodium flow path and DN detector block.