ON-LINE FAST FLUX MEASUREMENTS IN THE BR2 REACTOR

Background

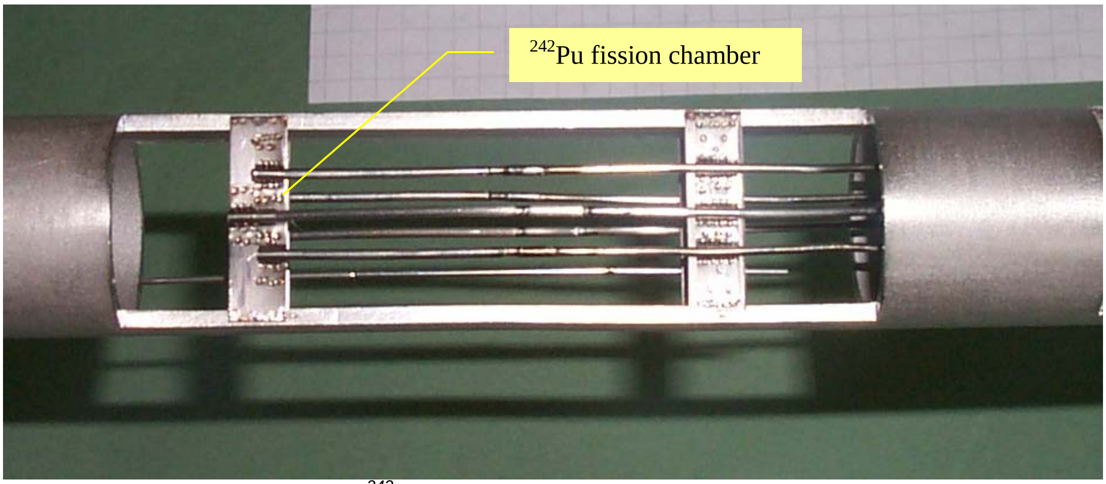
Since 2001, CEA-Cadarache and SCK•CEN are collaborating on the development and in-pile qualification of subminiature fission chambers (∅1.5 mm). Initially the efforts were concentrated on fission chambers for the in-pile measurement of thermal fluxes (with ^{235}U as fissile material). Meanwhile successful long-term tests of the prototypes have been performed in various environments: in low temperature (40-100°C) BR2 pool water (up to a thermal neutron fluence of 3×10^{21} n/cm²) and in the CALLISTO PWR loop (300°C, 155 bars). The long-term qualification of derived industrial detectors (Photonis CFUZ53) in CALLISTO is still ongoing.
However, for various types of irradiations in research reactors, the knowledge of the evolution of the fast neutron flux is even of more interest than the thermal flux data. Therefore the collaboration program was extended to the development and the in-pile qualification of subminiature or miniature fission chambers (with 3 mm diameter) for fast neutron detection, for which ^{242}Pu was selected as the optimal fissile material.
In order to achieve the on-line in-pile measurement of fast neutron flux, the fission chambers will be operated in the Campbelling mode (based on the mean square fluctuation of the detector current). In this mode the gamma induced contribution to the signal can be efficiently suppressed. Moreover, a data processing software will take into account the evolution of the fissile deposit in order to assess on-line the fast flux sensitivity and to correct for the low energy neutron contributions.

Objectives

The final objective is to qualify a Fast Neutron Detector System (FNDS) able to provide on-line data for local fast neutron fluxes in Material Testing Reactors. The on-line measurement of the fast neutron flux would contribute significantly to the characterization of the irradiation conditions during test experiments with materials and innovative fuel elements.

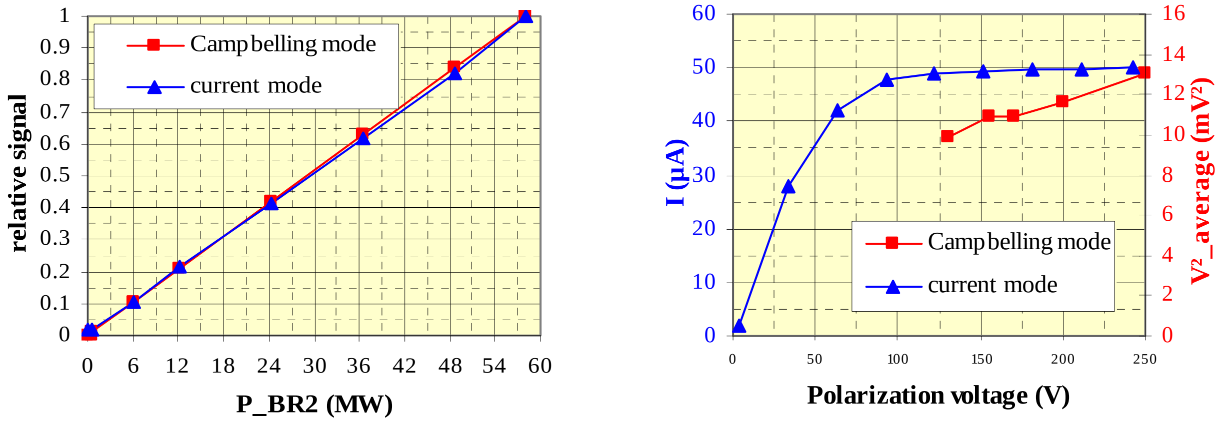
Principal results

In the BR2 thimble channels E30, G60 and K11 we tested a Ø1.5 mm ^{242}Pu fission chamber (see figure below), manufactured by CEA-Cadarache and equipped with a suitable cable to allow measurements in pulse, Campbelling and current mode. The linearity of the response, the current/voltage characteristics and the gamma suppression capability of the fission chamber were studied.



Detail of the experimental rig with the ^{242}Pu fission chamber together with other subminiature fission chambers.

The ^{242}Pu fission chamber shows a perfectly linear dependence on the reactor power, in current mode as well as in Campbelling mode (see figure on the next page). Moreover, the recorded I/V curve features a well-established saturation regime. The dependence of the Campbelling signal on the polarization voltage was also roughly determined, showing a more pronounced slope than in current mode. This behaviour will be studied in detail in an upcoming experiment.



The experimental data of the Pu-242 fission chamber: linearity of the response and polarization voltage dependence of the signals in current and Campbelling mode.

The main aim of the experiment was the verification of the suppression of the gamma-induced signal contribution in the Campbelling mode. This information was obtained from the detector data recorded during the hours following a reactor stop: the neutron flux drops very fast after the stop, while the gamma heating rate decreases more slowly according to a multi-exponential function. The figure below shows the normalized data and the fit curves for the ^{242}Pu fission chamber, corresponding to relative gamma contributions to the signal (at full reactor power) of 50 % in current mode and 0.6 % in Campbelling mode. So in the latter mode the gamma induced contribution is suppressed by almost two orders of magnitude.

Normalized Pu-242 fission chamber data just after the reactor stop: signals in current and Campbelling mode together with the fitted curves. After five hours the experimental rigs were unloaded from the reactor. The recorded thermal neutron flux and gamma heating rate data are also shown.

Future developments

The concept of a ^{242}Pu fission chamber operating in Campbelling mode as a fast neutron detector seems to be viable: in this mode the gamma-induced signal is almost completely suppressed – essentially the complete signal is due to neutron-induced fission. Although a large fraction of the signal indeed comes from fast neutrons, the sensitivity to lower energy neutrons is not negligible and will evolve during the detector lifetime. This contribution will be assessed by a code treating the evolution of the fissile deposit composition, in combination with a separate thermal flux measurement (using a ^{235}U fission chamber or a self-powered neutron detector). A dedicated signal acquisition system, including a module that performs these partial sensitivity calculations, is being developed. The complete FNDS system will be tested at BR2 by end 2008 or early 2009.

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Main reference

Patent being deposited.