IN-PILE INSTRUMENTATION DEVELOPMENT

Background

A proper interpretation of data from advanced irradiations in research reactors requires the on-line monitoring of neutron fluxes, gamma dose rates, central fuel rod temperatures, fission gas release pressures, small geometry changes, etc. Our activities in this field aim at a thorough understanding of the sensors' behaviour under the irradiation conditions in order to extract reliable real-time information.

Objectives

- On-line in-pile measurement of thermal and fast neutron fluxes and gamma heating rate;
- Study of parasitic currents and voltages in instrumentation cables due to radiation and temperature effects

Principal results

1. Wide-range in-core fission chamber testing

In collaboration with CEA-Saclay-DETECS fission chambers of type CFUR64 have been successfully tested in PWR simulating conditions. These fission chambers and their associated electronics provide the possibility to measure thermal neutron fluxes over a very wide range by automatic selection among different acquisition modes (see figures below). The drastic reduction of the gamma-induced signal when using the Campbelling mode is of particular interest for the development of a fast neutron flux detector (see item 3).

2. Qualification of sub-miniature fission chambers of type CFUZ53

After the testing of CEA sub-miniature fission chambers for the in-core detection of high thermal neutron fluxes, first prototypes of their industrial version (CFUZ53 type from the PHOTONIS company) were qualified in the CALLISTO loop of the BR2 reactor in PWR-like conditions (see photo below). Various parameters were investigated: neutron sensitivity, linearity to thermal neutron flux, current/voltage characteristics, gamma contribution, temperature effects and long term behaviour (mechanical integrity, uranium burn-up). We also compared the experimental data with results from a fission chamber theoretical model. The CFUZ53 signals show consistent signals in PWR conditions up to thermal neutron fluences beyond 2×10^{20} n/(cm²·s).

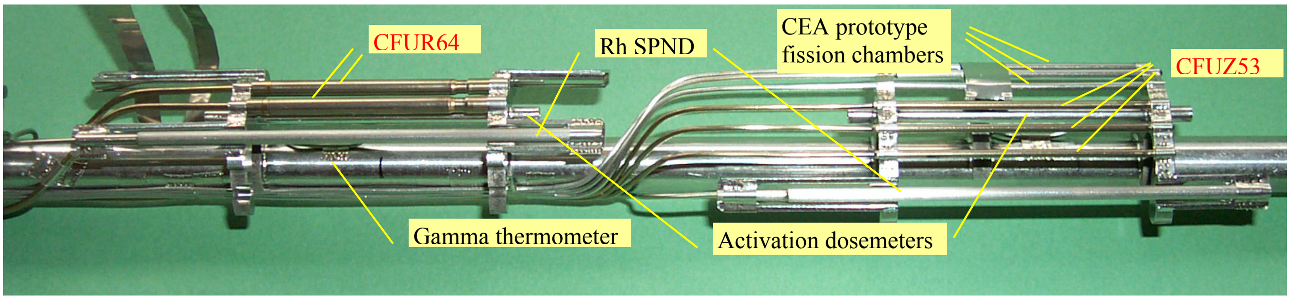
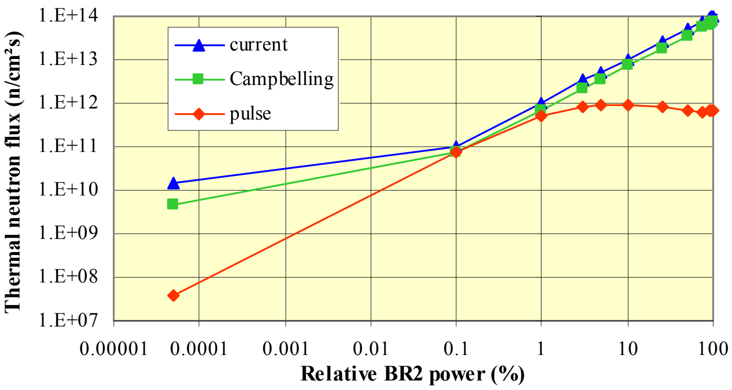


Photo of the experimental arrangement for the testing of the CFUZ53 and CFUR64 fission chambers, including the reference sensors for independent neutron and gamma field determination.



Raw thermal neutron flux data recorded on-line using a CFUR64 fission chamber as a function of relative BR2 power, according to the three measurement modes indicated. Depending on the flux range, the data acquisition system automatically selects the appropriate mode, yielding a linear flux response over a very wide range.

3. Development of an on-line fast neutron flux detection system

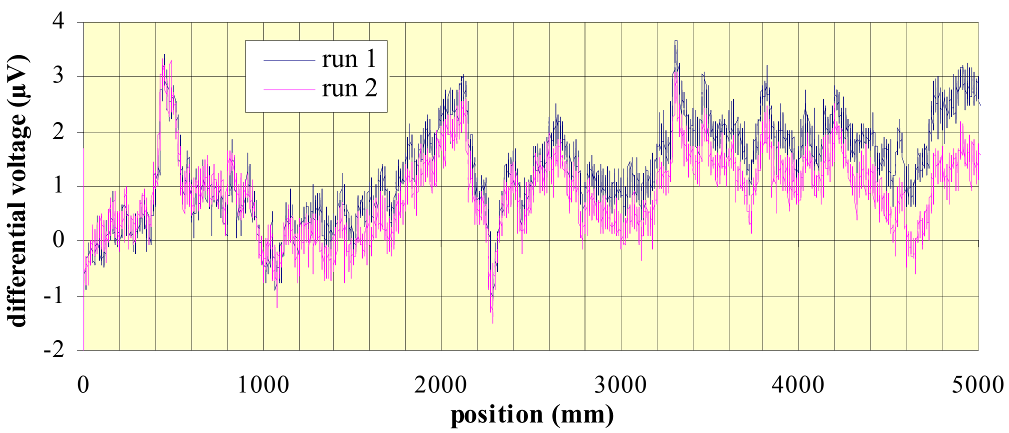
In the framework of the Joint Instrumentation Laboratory which is being set up between CEA and SCK•CEN a research program was defined for developing an on-line fast neutron flux detection system based on ^{242}Pu subminiature fission chambers. Test irradiations were performed to determine the fast neutron sensitivity as well as the relative signal contributions from thermal neutrons and gammas; the data are under analysis.

4. Gamma-selective self-powered detector modelling and testing

Another topic of the Joint Instrumentation Laboratory concerns the development of a gamma-selective self-powered detector based on a bismuth emitter design, in collaboration with CEA-Saclay. First gamma irradiation tests carried out at CEA-Saclay show promising results, in qualitative agreement with Monte Carlo model calculations performed at SCK•CEN.

5. Radiation and thermally induced currents and voltages in mineral insulated cables

The combined effects of radiation and temperature gradients on cable currents and voltages were studied by irradiation tests in the BR2 reactor. As a preparation, purely thermal tests were performed using a scanning oven, establishing a well defined temperature profile (ranging from 20°C to 305°C). Thermally induced differential voltages in mineral insulated cables with copper, stainless steel and nickel cores have been measured, before and after 16 hours' exposure of cable sections to 305°C and 720°C. For fresh Cu core cables distinct variations in the thermal gradient induced voltage with amplitudes of a few µV were observed (see figure). For stainless steel core cables, similar amplitudes were found, but the axial variations are smoother. Similar tests with Ni core cables show slow variations with amplitudes as large as 50 µV. After exposure of the cables at 305°C, hardly any change was observed. For copper core cables exposed to 720°C, changes in Seebeck coefficient lead to voltage changes of the order of 1 µV, which can be interpreted in terms of a simple model.



Recorded thermally-induced differential voltages between the ends of a Cu core cable with a 103 cm long oven at 305°C scanning over the cable (two successive runs) as a function of the oven position relative to a reference starting point.

Future work

We will continue the development of in-pile instrumentation, with emphasis on the research in the framework of the SCK•CEN-CEA Joint Instrumentation Laboratory (fast neutron detection system, gamma selective self-powered detector,…)

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Main references

L. Vermeeren, *"Project IRINA: On-line monitoring of thermal neutron fluxes using SPNDs",* SCK•CEN-R-4207, August 2005.

M. Wéber, *"Project IRINA: irradiation report"*, SCK•CEN-R-4266, November 2005.

L. Oriol, Ch. Blandin, S. Breaud, L. Vermeeren, and M. Wéber, *"In-pile CFUZ53 sub-miniature fission chambers qualification in BR2 under PWR conditions"*, TRTR-IGORR meeting, Gaithersburg, MD, USA, September 12-16, 2005.

L. Vermeeren, "*Report on thermal effects on RIEMF for selected MI cable coils: study of thermal induced differential voltages along copper and stainless steel core MI cables*", Final EFDA-report (part 1 of 2), TW4-TPDC-IRRCER Del.6, October 2005.

L. Vermeeren, "*Experimental study of radiation-induced currents in copper and stainless steel core mineral-insulated cables in the BR2 research reactor*", Fus. Eng. and Des. 74, 885-889 (2005).