SCK•CEN THE BELGIAN NUCLEAR RESEARCH CENTRE

REBUS-BWR INTERNATIONAL PROGRAMME AT THE VENUS CRITICAL FACILITY

Background

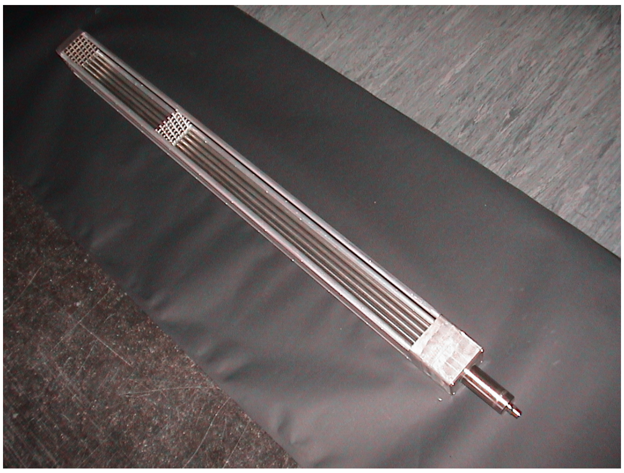
Present criticality safety calculations of irradiated fuel often have to model the fuel as fresh fuel, since no precise experimental confirmation of the decrease of reactivity due to accumulated burn-up exists. The disregard of this so called burn-up credit limits the stacking density of spent fuel and hence has serious economical implications for transport, storage and reprocessing of irradiated fuel. For long-term geological storage it is almost imperative to apply burn-up credit.

Objectives

The aim of the REBUS programme (Reactivity Tests for a Direct Evaluation of the Burn up Credit on Selected irradiated LWR fuel bundles) is to establish an experimental benchmark data base for the validation of reactor physics codes for the calculation of the loss of reactivity due to burn-up for LWR fuel.
The present second phase - following a first PWR UO_2 and MOX fuel phase carried out 2002-2004 - studies the reactivity effect induced by the burn-up of BWR high burn-up MOX fuel rods together with a thorough non-destructive characterisation of the irradiated BWR MOX rods and a radiochemical analysis of a representative sample from the irradiated BWR MOX fuel.

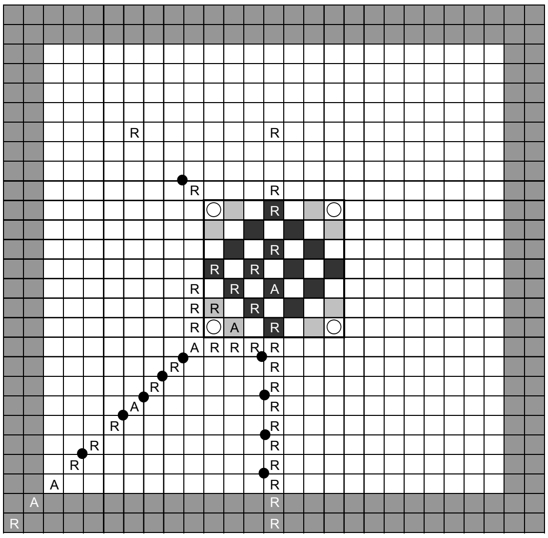
Principal results

The fuel involved is industrial spent MOX fuel rods extracted from 9×9 BWR assemblies from the German Gundremmingen nuclear power plant. Out of the ~ 4 m long industrial rods, 16 ~ 1 m rodlets – fitting in the VENUS facility – were successfully refabricated. The burn up of these rodlets ranges from 50 to 70 GWd/t_M. Their geometry was accurately measured by profilometry and their axial burn-up profile by combined gross gamma scanning and gamma spectroscopy. In order to preserve the contamination-free water pool of the VENUS critical facility, the refabricated rodlets were verified for their leak tightness by He leak testing, were extensively cleaned with the MEDOC process (Metal Decontamination by Oxidation with Cerium – developed at SCK•CEN) and subsequently subjected to a second He leak-test. All these measures resulted in an acceptable strongly reduced β-γ-activity transfer to water and insignificant α-activity transfer from the spent fuel rodlets.



The REBUS bundle

The 16 rodlets were then assembled in the REBUS bundle in a 1 over 2 loading scheme (to increase the reactivity effect), together with 8 fresh MOX rods that are positioned near the corner structural tubes. The REBUS bundle was transferred from the hot-cells, were all foregoing preparatory works were performed, towards the VENUS facility in a special designed REBUS container (appropriate for loading the bundle in the VENUS facility) that was in his turn enclosed in a transport container (suited for outdoors inter-building transport).



REBUS BWR MOX configuration consisting of a central 7x7 test zone surrounded by a pure UO_2 feeding zone. A and R stand for the axial and radial fission rate measurement positions. The black dots indicate axial flux measurement positions.

REBUS container on top of VENUS

At the VENUS facility, the REBUS container was positioned on top of the reactor and after closing the reactor room the bundle was lowered into the VENUS reactor remotely. The REBUS-BWR experiment used the same core layout as the foregoing REBUS-PWR experiment, i.e. the driver zone is made up of a square 27x27 configuration of fresh VENUS UO_2 fuel rods. In this way advantage is taken of the work already performed in the PWR phase: the configuration with the irradiated MOX BWR bundle is compared against the REBUS-PWR one with fresh PWR MOX fuel rods.

The critical water level together with the reactivity coefficient of the water level was determined. The axial and radial fission-rate distribution outside the REBUS bundle was derived by γ-scanning of specific rods that were unloaded after one day irradiation at full power (max. flux 5×10^9 n/cm^2/s). Furthermore, the γ-activity analysis of Co foils – being mounted both inside the bundle and outside in the feeding zone – provided the radial Co-reaction distribution from which the relative radial flux distribution can be derived.

The experimental programme was successfully carried out and the REBUS bundle transferred back to the hot-cell where the bundle was disassembled. As anticipated, the water of the VENUS facility showed an increased β-γ activity up to 3000 Bq/l and no increase in α-activity. The water could easily be evacuated and the VENUS vessel and associated hydraulic circuits easily were then cleaned to remove the residual activity.

At the hot-cells, a representative radiochemical sample was cut out of one of the rodlets. A radiochemical analysis will be performed to determine the top 19-absorbing nuclides, representing almost 80% of the neutron absorbing power, together with different burn-up indicators and the main minor actinides. This analysis has started and is scheduled to finish around summer 2006.

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Main reference

P. Baeten, P. D'hondt, L. Sannen, D. Marloye (BN), B. Lance (BN), A. Renard (BN), J. Basselier (BN), *"The REBUS-PWR Experimental Programme for Burn-up Credit"*, Integrating Criticality Safety into the Resurgence of Nuclear Power, Knoxville, Tennessee, September 19–22, 2005, on CD-ROM, American Nuclear Society, LaGrange Park, IL (2005)