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Calculations and Measurements for the Full-Core Conversion of the WWR-M Research Reactor in Ukraine

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In accordance with the program of pilot usage of LEU fuel approved by the Ukrainian Regulatory Committee, most burned HEU fuel assemblies of the WWR-M research reactor were successively replaced by fresh LEU fuel. By using this way, neutronic performance of the reactor remained almost the same as with HEU fuel but such the conversion progressed very slowly. Thus, the new full-core conversion program with simultaneous replacement of all remaining HEU fuel by fresh LEU fuel was developed.

The models applied for the conversion safety analysis were validated against measured data, which included critical experiment results for fresh fuel assemblies and measured neutronic distributions in real WWR-M reactor core. However, because of essential decrease of the number of fuel assemblies in the core (from 210 to 72), a lot of beryllium blocks had to be loaded into the reactor core. Most of these blocks were not used more than 40 years and information of their irradiation history was not available. Thus, excess reactivity for the new LEU core was difficult to calculate accurately because of unknown He-3 poisoning.

To provide safety of the new core loading, conservative approach was used. Irradiated beryllium blocks with unknown He-3 poisoning were assumed to be fresh, and 15 aluminum blocks were loaded for the nonce instead of beryllium to decrease excess reactivity. Moreover, neutron flux was being monitored all the time during the core loading to estimate subcriticality and worth of the control and safety rods.

When criticality was reached, excess reactivity and He-3 poisoning were estimated. Since He-3 poisoning was estimated to be high, 15 temporary aluminum blocks were replaced by beryllium ones. Then worth of the rods and excess reactivity were measured. By using comparative reactivity measurements, the beryllium blocks with the highest poisoning were detected and moved far away from the fuel to diminish their influence on the neutronics and thermal-hydraulics parameters of the core. Since such beryllium shuffling changed the worth of the rods and excess reactivity essentially, they were measured again. This measurement was in good agreement with calculation, so safety analysis was validated for the new LEU core.

Drop of the reactor power and number of fuel assemblies in the new core resulted also in essential decrease of fast and intermediate neutron flux in beam tubes. To solve this problem, LEU core configuration was optimized. Moreover, dependence of the number of fuel assemblies in the core and maximum allowed power of the reactor on LEU fuel burnup was estimated. Using this dependence, it was estimated how transient core configuration should be changed with LEU fuel burnup to provide sufficient fast and intermediate neutron flux in beam tubes. Then, placement of fuel assemblies and beryllium blocks in the core was optimized for each core reload during transient period to satisfy all the safety requirements and provide high neutronic performance of the reactor.

Organization

Institute for Nuclear Research

Country

Ukraine

Author: Dr MAHLERS, Yuri (Institute for Nuclear Research)

Co-author: MAKAROVSKY, Vladimir (Institute for Nuclear Research)

Presenter: Dr MAHLERS, Yuri (Institute for Nuclear Research)

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