CALCULATION OF MIXED HEU-LEU CORES FOR THE HOR RESEARCH REACTOR WITH THE SCALE CODE SYSTEM

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ABSTRACT

The HOR reactor of Interfaculty Reactor Institute (IRI), Delft, The Netherlands, will be converted to use low enriched fuel (LEU) assemblies. As there are still many usable high enriched (HEU) fuel assemblies present, there will be a considerable reactor operation time with mixed cores with both HEU and LEU fuel assemblies. At IRI a comprehensive reactor physics code system and evaluated nuclear data is implemented for detailed core calculations. One of the backbones of the IRI code system is the well-known SCALE code system package. Full core calculations are performed with the diffusion theory code BOLD VENTURE, the nodal code SILWER, and the Monte Carlo code KENO Va. Results are displayed of a strategy from a HEU core to a mixed HEU-LEU core and eventually a LEU core.

INTRODUCTION

Like many research reactors, the HOR reactor of Interfaculty Reactor Institute (IRI), Delft University of Technology, The Netherlands, will be converted to use LEU fuel assemblies. The conversion from HEU to LEU will be performed gradually by stepwise introduction of LEU fuel. A conversion study, safety analysis, and review of the HOR with HEU, LEU and mixed HEU-LEU fuel operation were performed, and a core conversion program including the licensing aspects was developed[1]. A specific conversion strategy was analysed, starting the process with the so called HEU compact core consisting of 20 fuel assemblies and as many beryllium reflector elements. Reloading is done by replacing HEU assemblies by LEU assemblies starting at the outer boundary of the core. Figure 1 gives an overview of a mixed HEU-LEU core with 8

HEU assemblies (including 4 control assemblies), 12 LEU assemblies, and 21 beryllium metal reflector elements. The central irradiation facility (CIF) is in the centre of the core.

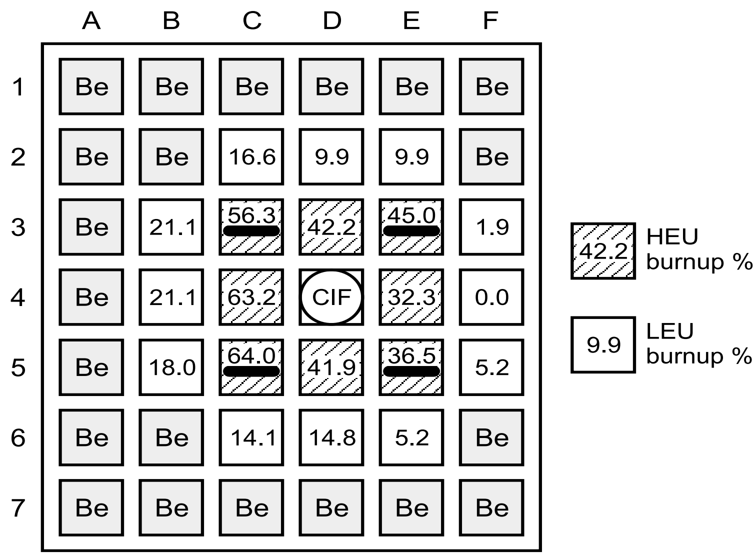

Figure 1 Overview of a mixed HEU-LEU core

Figure 2 shows the cross section of a standard HEU fuel assembly. In the case of a LEU fuel assembly read the following dimensions: cladding thickness 0.35 mm and flow channel 3.0 mm instead of 3.1 mm. The control rod assemblies have 10 fuel plates for both HEU and LEU fuel.

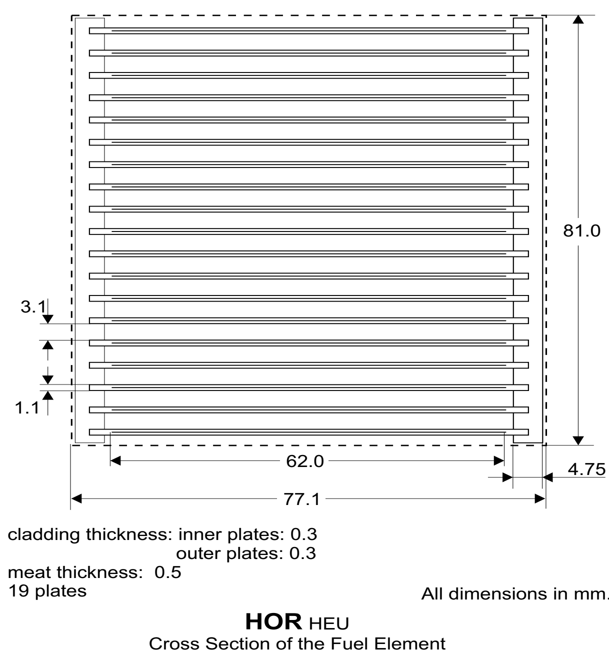

Figure 2 Cross section of a HEU fuel assembly of the HOR

At IRI the INAS (IRI-NJOY-AMPX-SCALE) code system and evaluated data is used for reactor physics calculations (Figure 3).

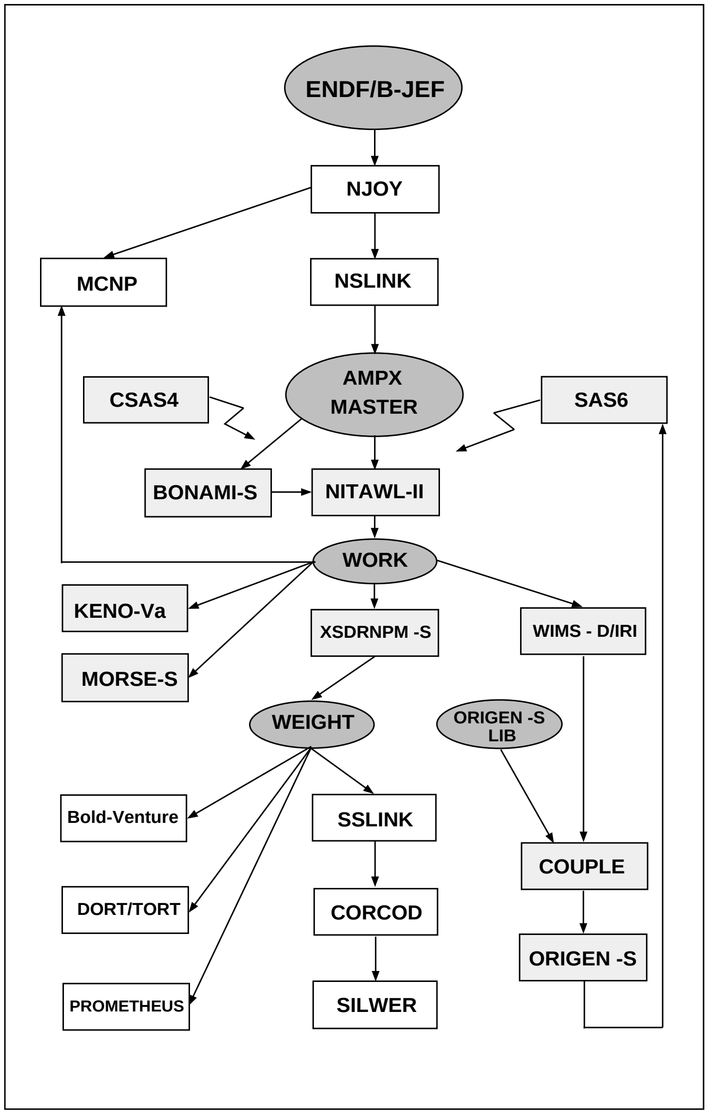

Figure 3 Overview of the INAS code system

One of the backbones of the INAS code system is the well-known SCALE[2] code system. This system is well documented, widely used, and accepted. It includes modules for resonance, cell, and depletion calculations. One-dimensional transport theory (S_n method) and/or Monte Carlo (three-dimensional) methods can be used as well. The basic library is the AMPX MASTER[3] library. This is a fine-group structured data library including resonance parameters, one- and two-dimensional cross sections for neutron and gamma reaction types, and some general information. The fine-group structure for neutrons used is 172 energy groups (XMAS). The library[4] can be generated from ENDF/B, JEF or JENDL evaluated data files using the NJOY[5] cross section processing code. The fine-group structured output data from NJOY can be converted to AMPX MASTER library format with the interface code NSLINK[6] (NJOY-SCALE-LINK). The SAS6[7] sequence can be used for depletion calculations. This sequence is based on the SAS2H sequence of the SCALE system, but the one-dimensional cell calculations by XSDRNPM are replaced by the two-dimensional lattice code WIMS/D.

The XSDRNPM code can be used to generate cell or zone weighted few-group microscopic cross sections. These cross sections can be used for full core calculations with the diffusion theory code BOLD VENTURE[8] and the two- and three-dimensional transport codes DORT and TORT[9]. The interface code SSLINK[10] (SCALE-SILWER-LINK) can be used to generate homogenised macrocopic cross sections for the three-dimensional nodal code SILWER[11]. The CORCOD code computes fits to tabulated homogenised few-group cross sections from XSDRNPM versus independent system variables such as burnup or different temperatures.

RESULTS

Calculations for the conversion from HEU to LEU are performed using an AMPX MASTER library based on JEF 2.2 data in 172 neutron energy groups. Depletion calculations are done using SAS6 for both HEU and LEU fuel. The densities of the nuclides used are calculated by SAS6 for 0, 10, 20, 30, 40, 50, 60, and 70% burnup of ^{235}U respectively. These densities are used in the cell calculations to weight and condense (to five neutron energy groups) the cross sections for HEU and LEU fuel respectively. These cross sections are used in BOLD VENTURE for 2-D full core calculations and in SILWER for 3-D full core calculations. The 3-D Monte Carlo code KENO Va uses resonance shielded cross sections in 172 energy groups.

The geometry as shown in Figure 1 is used for different HEU, HEU-LEU (mixed), and LEU cores. The different mixtures used of HEU-LEU fuel are given in Table 1.

core	#HEU	#LEU
HEU	20	0
mix1	18	2
mix3	14	6
mix5	10	10
mix7	8	12
mix9	6	14
mix11	4	16
mix13	1	19
LEU	0	20

Table 1 HEU and LEU mixtures used

For the full core calculations with the codes BOLD VENTURE, SILWER, and KENO Va, the following initial conditions were used: begin of cycle (BOC), Xenon free, temperature 293 K, and all (four) control rods withdrawn. The Monte Carlo code KENO Va is used with a detailed representation of all individual fuel plates in the assemblies and all relevant reactor components. The results of the effective multiplication factor (k_{eff}) for the different mixtures are shown in Figure 4.

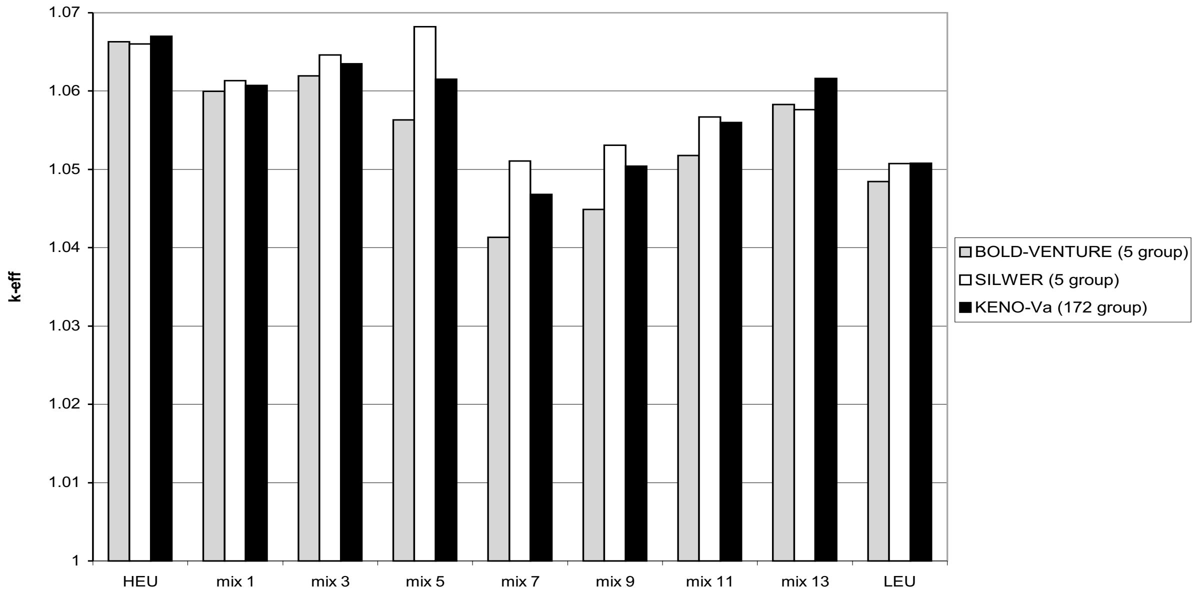

Figure 4 k_{eff} for different mixtures HEU-LEU

CONCLUSION

From the results of the calculations it follows that there is a good agreement between the codes BOLD VENTURE, SILWER, and KENO Va for HEU and LEU cores. There is a difference in k_{eff} for the mixed HEU-LEU cores, especially for the mixtures 5 to 9. For these mixtures there is a well mixed core of HEU and LEU assemblies (see Table 1). In the cell and burnup calculations, the presence of strongly different HEU and LEU fuel assemblies adjacent to each other introduces new aspects in the core calculations. In both cell and burnup calculations a white boundary condition is used, resulting in a net zero current at the boundary of an element. This boundary condition is not valid for HEU and LEU neighbours. The KENO Va results are not affected by this option, because no cell calculations are needed. The KENO Va results can be used as a 3-D reference for the methods (approximations) as used in the sequence XSDRNPM, BOLD VENTURE, and SILWER. Further investigations will be necessary to improve the cell calculations for mixed HEU-LEU fuel by using other boundary conditions or cell geometries. The spread of the calculated values of k_{eff} is < 1% Dk/k. It can be expected that further investigations will most likely lead to an improvement of the spread between the results of the different codes used to < 0.5% Dk/k . It can be concluded that the INAS code package based on the SCALE code system can be used with confidence for the calculation of mixed HEU-LEU cores for the HOR research reactor.

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