Processing of Nuclear Ship Savannah Fuel

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INTRODUCTION

Low enrichment (3.9 wt % ^{235}U) unirradiated fuel assemblies for the Nuclear Ship (NS) Savannah have been stored in their original shipping containers at the Oak Ridge Y-12 National Security Complex (Y-12 NSC) for many years. These fuel assemblies have been transported to the Oak Ridge National Laboratory (ORNL) and disassembled into fuel rods that have been packaged and shipped to a commercial fuel fabricator. Extensive nuclear criticality safety studies were performed to support evaluation of the transport and processing activities.[1]

FUEL ASSEMBLIES

Each fuel assembly nominally contains 8.55 kg ^{235}U. Their overall length is about 2 meters and stainless steel clad fuel rods are arranged in an 11 by 11 lattice with the four corner rods replaced by a stainless steel tie rod (117 fuel rods). The fuel rod center-to-center spacing (pitch) is 0.780 in. Each fuel rod is composed of 2 individually sealed axial segments and each segment contains nominal 0.5 in. diameter by 0.625 in. long UO_2 fuel pellets with the UO_2 at about 95% of theoretical density. Each fuel assembly has a top plate, middle spacer plate, and bottom plate with the fuel rod segments threaded into each other through the middle spacer plate.

CODE VALIDATION AND COMPUTATIONS

The CSAS25 sequence in SCALE 4.4a was used to execute the KENO-V.a Monte Carlo code.[2] The 238-neutron-energy-group SCALE library, which is based primarily on Evaluated Nuclear Data File/B-V (ENDF/B-V) data, was used for all computations. The code and cross sections were validated for this work using 30 critical experimental configurations selected from the International Handbook of Evaluated Criticality Safety Benchmark Experiments.[3] Specifically, all the experimental configurations in LEU-COMP-THERM-001, 002, 007, and 019 were modeled, along with the first four experiments of LEU-COMP-THERM-009. Validation results were statistically evaluated to determine that any $k_{eff} + 2\sigma < 0.96$ could be considered acceptably subcritical. The result included a subcritical margin of 0.029 in k_{eff}.

The k_{eff} of a single, undamaged fuel assembly moderated and reflected by water was calculated to be ~0.81. A number of computations were performed to examine the reactivity of square and triangular lattices of fuel rods as a function of fuel rod pitch and number of fuel rods. All the lattices approximated a cylindrical shape, were moderated and reflected by water, and had rod axes parallel with rods uniformly spaced. Two modestly conservative fuel rod models were used, one to simulate the individually sealed axial segments ("half-length rods") and the other to simulate two axial segments end-to-end ("full-length rods") as would be found in a fuel assembly. Results indicated that 117 full length rods in either square or triangular arrangement are subcritical at any pitch and that 234 half-length rods can be made critical if the pitch is between 0.8 in. and 1.2 in.

ON-SITE TRANSPORT

The fuel assemblies were stored at the Y-12 NSC in U. S. Department of Transportation (DOT) Special Permit (SP) 5977 packages in which they had been received. The 16 gauge steel outer body of each package was nominally 39 in. square by 92 in. One fuel assembly was approximately centered within a wood braced plywood box within each package and rubberized mohair was extensively used for cushioning.

Although the content of one fuel assembly can technically support criticality, it was determined that a transportation accident would have to very selectively accomplish several things before criticality could occur. Specifically, essentially all the half-length rods would have to be disconnected from each other and from the two end plates, rearranged into an approximately cylindrical relatively compact single lattice, and have an average pitch over a very narrow range. Also, this configuration would have to be effectively moderated and reflected

(e.g., due to immersion in water) in order for a criticality potential to exist. The risk was demonstrated to be so small that transport from the Y-12 NSC to ORNL was accomplished as an on-site transfer with a limit of one fuel assembly at a time.

STORAGE AND PROCESSING AT ORNL

Each SP 5977 package was received into the Building 3525 Irradiated Fuel Examination Facility (IFEF) and no more than four packages were stored at a time. Disassembly was limited to no more than one fuel assembly at a time and removed fuel rods were packed into DOT specification 2R containers that were used as the inner containers for DOT specification 6M shipping packages. The disassembly, storage, and handling operations were carefully evaluated and it was determined that the probability of a criticality accident was sufficiently low that a criticality accident alarm system was not required.

Disassembly was accomplished using ordinary hand tools and operations proceeded smoothly. The total inventory of seven fuel assemblies was processed into fuel pins that filled 28 DOT specification 6M shipping packages that were transported to the fuel fabricator aboard a commercial transport vehicle.

CONCLUSION

The on-site transport, disassembly, packaging, and off-site transport of historic fuel materials was safely accomplished and was compliant with contemporary requirements.

REFERENCES

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3. International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95)03, NEA Nuclear Science Committee, September 2002 Edition.