STATUS OF BURNUP CREDIT IMPLEMENTATION IN SWITZERLAND

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Abstract

Burnup credit is currently not used for the storage of spent fuel in the reactor pools in Switzerland, but credit is taken for integral burnable absorbers. Interest exists to take credit of burnup in future for the storage in a central away-from-reactor facility presently under construction. For spent fuel transports to foreign reprocessing plants the regulations of the receiving countries must be applied in addition to the Swiss licensing criteria. Burnup credit has been applied by one Swiss PWR utility for such transports in a consistent manner with the licensing practice in the receiving countries. Measurements of reactivity worths of small spent fuel samples in a Swiss zero-power research reactor are at an early stage of planning.

1. GENERAL SITUATION OF SPENT FUEL MANAGEMENT IN SWITZERLAND

Spent fuel from all the Swiss nuclear power plants (3 PWRs, 2 BWRs) is stored in pools at the reactors. The PWRs have been refurbished with high-density racks employing absorber sleeves with boron-containing materials. A substantial part of the spent fuel, though varying from plant to plant, has been shipped to France and the United Kingdom for reprocessing. For the future, utilities are also considering long-term storage of spent fuel, particularly if this alternative should prove economically more attractive than reprocessing. A central storage facility for all types of radioactive wastes, which will also provide room for dry storage of spent fuel in casks, is currently under construction.

All transports of spent fuel from Swiss reactors to date have been to foreign reprocessing plants. Moreover, no transport containers have been originally designed and licensed in Switzerland. For these reasons, licensing of transports is not done completely independently in Switzerland. Rather, licensing of spent fuel shipments from the Swiss nuclear power plants is based on the licenses for the containers obtained in their countries of origin, and the regulations for transport and reprocessing in the receiving countries must be taken into account.

2. REGULATORY STATUS

The standards and guidelines applied for licensing in Switzerland allow the use of burnup credit. For each fuel assembly to be loaded into a spent fuel management system applying burnup credit, it must be proved, both from the reactor operating records and by a burnup measurement, that it exceeds the minimum burnup on which the burnup credit license is based.

The licensing of storage systems is based on the US NRC Regulatory Guide 1.13, Appendix A. The containers used for spent fuel transports to foreign reprocessing plants are licensed in their countries of origin. The original licenses are validated for the use in Switzerland based on an independent review of the original safety assessment by the Swiss authorities, in which amongst other considerations the conformity with international standards (IAEA transport regulations) is verified.

3. CURRENT AND INTENDED USES OF BURNUP CREDIT

No credit for burnup is taken for the storage of spent fuel in the reactor pools in Switzerland and there is no intention currently to do so in the future. The existing storage pools have sufficient margin to accommodate fuel with higher initial enrichment than originally used. Credit is taken, however, for integral burnable absorbers, i.e., the storage pools are designed and licensed for the peak reactivity of the fuel in its lifetime under consideration of burnable absorbers. The licensing of BWR pools is based on the maximum k_{inf} of the fuel assemblies at cold conditions in reactor core geometry.

There is no dry storage of spent fuel in Switzerland at present. A central away-from-reactor storage facility is under construction, and the first proposals for storage casks have been submitted to the licensing authorities. Utilities are interested in taking credit of burnup for storage in this facility, but no concrete action has yet been taken, and the level of burnup credit to be applied is not yet defined.

All the shipments of spent fuel from the Swiss reactors have been to foreign reprocessing plants. Therefore, these transports have to fulfill not only the Swiss licensing criteria, but also those of the receiving countries and those of the original licenses of the transport casks.

To date, burnup credit has only been taken by one PWR utility for fuel whose initial enrichment exceeds the licensed limits of the reprocessing plants. For reprocessing in France, the following conditions, which are consistent with the French regulations, are applied:

- For initial enrichments up to 3.5%, no credit is taken of burnup, because the reprocessing plant and the transport casks are licensed for fresh fuel with 3.5% enrichment.
- For initial enrichments between 3.5% and 3.75%, a qualitative burnup check, showing that the assembly has been irradiated, is required.
- For initial enrichments exceeding 3.75%, a quantitative burnup measurement along the entire assembly length has to be performed. The average burnup of the least depleted 50 cm at the top of the active length has to exceed an enrichment-dependent limit. Burnup credit is taken for uranium and plutonium, but not for higher actinides or fission products.

The British reprocessing plant has a higher licensed limit for the initial enrichment. Burnup credit has been accepted for shipment of a few assemblies exceeding this limit based on the study performed for the reprocessing in France.

4. COMPUTATIONAL METHODS USED

A large number of criticality calculations for storage pools have been performed since the 1970's by Paul Scherrer Institute (PSI) as a small part of its activities in the field of light water reactor neutronics. Calculations have been done for the Swiss utilities, manufacturers of storage racks, and the licensing authorities. For all these calculations the BOXER [1] code developed at PSI was used. BOXER is a cell and two-dimensional transport and depletion code primarily intended for the generation of assembly-averaged few-group cross sections for core simulations. It has sufficient flexibility and calculational accuracy to allow also the modeling of more complex configurations, with the limitation that the two-dimensional transport calculations are performed in Cartesian x-y geometry and with homogenized cells.

The BOXER cross section library is based on JEF-1 nuclear data (except Gd-155 from JENDL-2 and Zircalloy-2 from ENDF/B-4). It contains cross sections in 70 energy groups (69 group WIMS structure plus one group between 10 and 15 MeV). Resonance cross sections are given in point wise lists between 1.3 eV and 907 eV and tabulated as a function of temperature and dilution cross section at higher energies. The burnup chains comprise 34 actinides (from Th-232 through Cm-248), 55 explicit fission products, and two pseudo fission products.

In BOXER, self-shielded resonance cross sections are determined by a point wise two-region collision probability calculation between 1.3 and 907 eV, and by tabular interpolation above this range. The group wise cell calculation is performed by means of an integral transport method in cylindrical geometry. The two-dimensional transport calculations are performed using a transmission probability integral transport method for homogenized cells. Depletion calculations are performed using reaction rates collapsed to one group by weighting with the fluxes from the two-dimensional calculation for each material in the configuration.

BOXER has been validated successfully against a large number of critical experiments and international benchmark problems, including both uniform lattices and configurations containing features representative of storage pools and transport casks (such as neutron absorbers and metal reflectors). The depletion calculations were verified against Yankee-Rowe assay results and benchmark problems such as the OECD/NEA benchmarks on burnup credit and on recycling of reprocessed uranium.

The MCNP continuous energy Monte Carlo code is also available at PSI, but it has not been used for criticality calculations to date.

5. RESEARCH AND DEVELOPMENT ACTIVITIES

5.1. Analytical

PSI has participated in some of the OECD/NEA criticality safety benchmarks since the benchmark group was founded. The current series of benchmarks dealing with burnup credit have also been calculated with BOXER, and the results compare well with those of the other participants.

5.2. Experimental

A programme of LWR integral experiments is currently in preparation in the PROTEUS facility at PSI. PROTEUS is a driven, zero-power facility, in which the central test zone, which contains the lattice to be investigated, is subcritical. This test zone is surrounded by driver regions containing 5% enriched fuel moderated by heavy water and graphite. The test zone and the driver are separated by a buffer consisting of tightly-packed natural uranium metal rods in air (i.e. without moderator) which helps to spectrally decouple the two regions.

The LWR-PROTEUS experiments will be carried out in cooperation with the Swiss utilities and their fuel vendors and also be partly funded by them. In the first phase, scheduled to start in early 1998, the test zone will consist of 9 real, full-length BWR fuel assemblies. The major part of the measurements in this phase will deal with pin power distributions in these assemblies. The aim of these measurements is to validate design codes for the calculation of modern assembly types which have much stronger heterogeneities (e.g. internal water regions, high number and absorber content of burnable poison rods) than most of the experiments against which the computational methods were originally tested.

A second phase of the LWR-PROTEUS experiments, dealing with PWR lattices, is presently at an early stage of planning. The idea is to construct a test zone of real, full-length PWR fuel rods which, after completion of the measurements, will be reconditioned to actual fuel assemblies and loaded in the power reactor. As part of this PWR programme, it is planned (and project partners are very interested) to measure reactivity worths of small samples of spent PWR fuel with a range of burnups in this test zone. The configuration of LWR-PROTEUS with a long test zone (4 m) and a shorter driver (approx. 1 m) is very suitable for sample oscillation experiments, which allow the measurement of small reactivity changes (a few cents) with high accuracy. After the reactivity measurements, the samples will be analyzed for actinides and fission products in the PSI hot laboratory.

REFERENCES

[1] PARATTE, J.M., GRIMM, P., HOLLARD, J.M., "ELCOS, The PSI Code System for LWR Core Analysis, Part II: User's Manual for the Fuel Assembly Code BOXER," PSI Report 96-08, (February 1996).