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BURNUP CREDIT IN SPAIN

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Abstract

The status of development of burnup credit for criticality safety analyses in Spain is described in this paper. Ongoing activities in the country in this field, both national and international, are resumed. Burnup credit is currently being applied to wet storage of PWR fuel, and credit to integral burnable absorbers is given for BWR fuel storage. It is envisaged to apply burnup credit techniques to the new generation of transport casks now in the design phase. The analysis methodologies submitted for the analyses of PWR and BWR fuel wet storage are outlined. Analytical activities in the country are described, as well as international collaborations in this field. Perspectives for future research and development of new applications are finally resumed.

1. INTRODUCTION

Burnup credit has been taken in Spain for the criticality safety evaluation of spent fuel pools since 1990. The need for increasing the storage capacity of the on-site spent fuel pools by means of high-density storage racks led to the implementation of burnup credit, originally at PWR plants.

At present, credit to burnup is included in the criticality safety analysis of all the PWR plants in operation, 7 units, and credit to the presence and burnout of burnable absorbers (Gd) is given in the two BWR units in operation. The analyses refer to wet on-site storage in all cases, and cover a wide variety of fuel types for each plant. Full burnup credit is taken in all the licensed analysis, meaning that the neutron absorption due to fission product buildup is taken into account.

There is an ongoing dual-purpose cask design program in Spain, of which the first cask for PWR fuel has already been licensed assuming fresh fuel will be loaded. The possibility of taking credit for fuel burnup in the design of the new dry casks generation is currently under consideration, and will most probably be adopted. This decision will likely condition whether burnup credit will be taken for the design of the Interim Storage Facility that should be built in Spain to cover the time gap until the final repository is available. No decision has been yet taken about the latter.

2. REGULATORY STATUS

The use of burnup credit and partial credit for Boron in the criticality safety analysis of spent fuel pools is allowed by specific national regulations, published in 1990. These regulations have never since been revised, if they are scrutinised at the light of the current burnup credit knowledge and of the improvement of the codes and analytical methods, it has to be acknowledged that the technical details and other parts of their contents are now outdated. A revision of this rule is expected to be published in 2001.

The acceptance criteria now applied for recent analysis follow the technical positions of the NRC, that demand that the K-eff of the storage has to be below 1 with unborated water, including all the uncertainties, and below 0.95 assuming borated water, again including uncertainties.

No reference to the use of burnup credit for the design of spent fuel storage/transport casks, of the dry storage of spent fuel, or of the final repository, can be found in the national regulation. Given the fact that a new generation of burnup credit casks will be submitted for licensing in a few years, there is a clear need to define technical positions and acceptance criteria on schedule. It is expected that this work will be included in the revision of the regulation mentioned above.

3. BURNUP CREDIT ANALYSIS OUTLINE AND IMPLEMENTATION

Criticality safety analyses licensed up to date for the storage of PWR fuel follow the usual procedure of determining a reactivity equivalence curve. The curve relates the initial (fresh) enrichment of a given fuel bundle with the minimum discharge burnup needed to guarantee that the reactivity of that bundle is within the allowable limits for the system design. In those cases where different fuel types are (or have been) used in the plant, the most reactive fuel type under storage conditions is first determined, and the reactivity equivalence curve finally applied refers to the most reactive fuel type.

The calculation is performed in two steps. First, a fuel depletion calculation is performed to determine the evolution of the nuclide's concentration as a function of burnup, using a bounding irradiation history in the sense of maximising the spent fuel reactivity. Second, a criticality calculation is performed using the specific characteristics and tolerances of the spent fuel storage system.

Fuel depletion calculations necessary for burnup credit criticality safety analysis introduce new parameters and effects that should be taken into account to obtain an adequate (in the sense of bounding) reactivity result. The first effect comes from the spatial distribution of burnup in the fuel assembly. Depletion calculations are performed with 2-D lattice codes. The isotopic composition obtained is then used to calculate the reactivity of the spent fuel assuming that the fuel composition is uniform in both the radial and axial directions.

However, although a fuel assembly is characterised by an average burnup value, there is an axial burnup distribution in the fuel assemblies, the burnup level being higher in the centre and lower at the ends of the assembly. Whether this axial burnup distribution has an impact on reactivity or not, and how big the impact is, depends on the specifics of the fuel assembly type and on the details of the plant's fuel management scheme. So, it has to be determined on an application specific basis. As a consequence, burnup credit applications for storage have all taken into account the specific burnup distributions of the fuel operated at the specific plant.

For PWR fuel storage applications, the axial burnup shape effect on reactivity has been determined using burnup profiles coming from core follow data of the specific plant. A reactivity bias due to this effect is obtained for each burnup value on a 95/95 basis, and the reactivity of the uniformly burnt fuel assembly is corrected at each burnup value. The reactivity equivalence curve finally applied already includes this bias.

A direct measurement of the discharge burnup is not required for storage implementation of burnup credit. As a result, no burnup measurement method is available at the Spanish plants, and the discharge burnup is determined based on core following data coming from the reactor records. A problem associated to this prcatice is that core following methods are very different in quality among the plants, and still rather crud in some cases in which the older methods and procedures have not been replaced by modern on-line monitoring systems.

In the case of BWR fuel, the level of credit to fuel burnup given is in fact the consideration of the neutron absorption in the Gadolinia. Hence, it is not precisely burnup credit, although the calculations processes and needs are very similar. The approach followed is to first determine the most reactive lattice of all the specific designs of every fuel type used at the plant. This process can be complicated, given the wide variety of fuel types, and the extreme design flexibility of BWR fuel.

All the fuel is then assumed to be axially uniform with that lattice design. The burnup value at which the lattice reactivity is at its maximum (due to the decrease of the Gadolinia contents with burnup) is calculated, and the maximum lattice average enrichment that fulfils the reactivity limit for the storage is obtained. Hence, the analysis is inherently conservative because the maximum reactivity of the most reactive lattice is assumed to be the condition of all the fuel present in the pool.

The radial enrichment distribution of BWR fuel is not uniform, in order to adequately shape the radial power distribution and reduce the local peaking factor. This distribution has an effect on the lattice reactivity that has to be taken into account, because the enrichment distribution can be modified from cycle to cycle without changing other fuel bundle characteristics. It has been observed that the assumption of a uniform radial enrichment distribution is more reactive than any radial distribution with the same average value. Hence, a uniform enrichment distribution is used for the analysis.

Consideration of the axial burnup shape in BWR fuel is a rather difficult task. A process equivalent to that described for PWR fuel cannot easily be formalised for BWR fuel. The axial burnup shape of BWR fuel assemblies depends on too many factors, including the specific axial zoning design and the important axial variation of the depletion parameters (void fraction, temperature, flow...). Hence, fuel with the same burnup level can have very different axial burnup shapes, with a remarkable effect on reactivity. That is the basic reason why a bounding approach such as the one described above (limiting lattice at worst time in life) has to be used. A less restrictive approach has never been submitted for licensing.

4. BURNUP CREDIT RELATED ACTIVITIES IN SPAIN

There is no experimental program in Spain related to burnup credit, neither ongoing nor projected for the near future. All the activities performed up to now have been analytic in nature, and the experimental data needs have been covered in different ways.

As a result of an ongoing rethinking of the CSN research priorities, burnup credit related research has been identified as one of the fields were more regulatory work is expected in the coming years, specially that related to spent fuel transport applications. Therefore, it is expected that this issue will be rated as high priority, meaning that the participation of Spain in international experimental programs and activities could be better funded in the future.

Three Spanish organisations (two engineering companies and one University) have developed burnup credit analysis methodologies for spent fuel storage systems. All of them have already been licensed, and the regulatory authority has accepted their applications at least once. The oldest methodology of them all, applied to PWR fuel storage for the first time in 1989, is being now revisited and updated to include the developments attained in the field during this period, before additional applications are submitted. These new applications are anticipated due to the need of the plants to increase the fuel enrichment to face the power uprate process in which most of them are involved.

During licensing evaluations performed in the past years, it was observed that the specific characteristics of advanced fuel designs (axial zoning, enrichment distribution, integral burnable absorbers) could not be modelled in the SCALE system with the same level of detail used for traditional fuel. This lack of detail could have an impact on the quality of the depletion calculation, affecting both the spent fuel calculated reactivity and the source term obtained. A development work co-funded by ENRESA (state owned company responsible for radioactive waste management) and the CSN is going on at Oak Ridge National Laboratory to put in place a new calculation sequence (SAS-2D) in the SCALE system.

Spain also maintains an active participation in the Working Party on Nuclear Criticality Safety (formerly Burnup Credit Criticality Benchmark Group) of the OECD-NEA, and has been collaborating with IAEA activities in this field since they were started. Also, some collaboration with the US-NRC has recently been started, as well as bilateral cooperation with some South-American countries.