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NUCLEAR SCIENCE COMMITTEE

BURNUP CREDIT CRITICALITY BENCHMARK
SUMMARY OF MEETING HELD ON 17-18 JUNE 1992
CHÂTEAU DE LA MUETTE, PARIS
CONCLUSIONS OF THE NUCLEAR SCIENCE COMMITTEE
5 NOVEMBER 1992

NUCLEAR SCIENCE COMMITTEE
BURNUP CREDIT CRITICALITY BENCHMARK

Summary of Meeting held at OECD, Paris, 17-18 June 1992, and Conclusions of the Nuclear Science Committee, 5 November 1992

Introduction

Chairman G.E. Whitesides opened the meeting. For the many newcomers to the group he recalled briefly the history, purpose and achievements of the nuclear criticality safety benchmark group.

The main purpose of the group is to validate computational methods through international exercises.

The composition of the group has changed over the years in order to meet the evolving requirements from the criticality safety community. It has started as a group overseen by CSNI; during this phase criticality codes for spent LWR fuel transport containers and for large arrays of packages of fissile materials were investigated.

The next phase addressed criticality of fuel undergoing dissolution. Because more physics understanding is demanded in modelling these problems the group was transferred to NEACRP.

The work carried out in these two phases resulted in several reference reports and publications at conferences.

The new phase concerning burnup credit criticality was discussed during a short meeting held at the international conference on nuclear criticality safety (Oxford, September 1991) and the resulting work plan was submitted to the NEACRP. Following the recommendations of NEACRP the newly established Nuclear Science Committee (NSC) endorsed this activity. Burnup credit criticality moves ahead of the historically pessimistic criticality calculation approach in which fresh fuel is assumed to be present rather than spent fuel. This new approach shows how large the safety margins are and how plant or storage efficiency can be achieved together with a decrease of operational costs. The end goal is to find an approach which balances the two requirements of reducing costs and optimal safety.

The work plan is divided into 3 phases.

- The first looks at the effects of first order:
  The effect of taking into account burnup and build-up of major and minor actinides, the effect of presence of major and minor fission products.

- The second addresses the effects of spatial distribution of burnup. This is particularly important to verify whether or which simplifications are conservative; the effects observed here are of second order.

- The third phase addresses other special questions: it maybe a revisiting of Phase I and II for fuel other than for PWRs (Examples: BWR, MOX, etc.)

The objectives of this work are the intercomparison and assessment of quality of analysis computer codes, methods and data used in burnup credit criticality calculations.

Participants

The list of participants is provided as the last section. Not all were able to attend the meeting, but will exchange their views via correspondence.

Agenda

The agenda was adopted without modifications.

Discussion of Phase I - Simple PWR Fuel Cell

The specification of the benchmark concerned an infinite array of PWR spent fuel cells in which 12 actinides and 15 among the most important fission products were considered.

Makoto Takano reviewed the submitted results. For Phase I, 23 sets of results were submitted from 19 institutions in 11 countries. Additional institutions expressed the intention to participate in Phase II. France has participated with only one set of results although several were calculated, which were all highly consistent with each other. The results were presented both in tabular and in graphical form. The first part displayed multiplication factors, the second the different group structures and the energy spectra, parts 3-6 displayed adsorption rates production rates and nu-bar. Participants have each in addition commented their results. Results obtained with modelling not strictly conforming with the specification were identified. Some discrepancies may still be due to the fact that not all participants have submitted the results in the strict format requested, so that some data provided may be interchanged. It is important that these are identified so that a meaningful comparison can be made.

The following was observed for the results submitted by the time of the meeting:

the effect of burnup at 30 GWd/t results in a reduction of reactivity of 18 percent and of 24 percent at 40 GWd/t. This includes the effect of fission products which amounts approximately to 7 percent (15 nuclides). The effect of cooling from 1 to 5 years reduces reactivity by another 2 percent.

As far as the consistency of the results are concerned one observes a standard deviation of 500 pcm for the cases with no fission products. This is of the same order as observed in other benchmark studies concerning criticality calculations. However for the cases with fission products this discrepancy is much higher. This is an indication that there is a need to give a closer look at the fission product cross sections used. As previously observed in other

criticality studies, also in this case we find that calculations using ENDF/B-IV data predict uniformly a lower reactivity when compared with those using other evaluations. Not all participants have used the same approach in resonance self shielding nor have they applied it to the same set of isotopes. This is an additional source of discrepancy. The final report will show the effect of using resonance self shielding deterministic methods as compared to continuous energy Monte Carlo.

It was suggested that for describing the variation of reactivity it would be better to use the logarithmic formula $\log(k_f/k^i)$ in the tables of the final report (suffixes f and i stand for final and initial).

The chairman expressed thanks to M. Brady and M. Takano for their effort in providing the specifications of this benchmark and to M. Takano in particular for the excellent work in summarizing the results.

Further Actions decided for Phase I of the Burnup Credit Criticality Benchmark (BUC)

During the meeting, held on 17th and 18th June, it was decided to structure Phase I into two parts: one, called I-A, which extends Phase I of the BUC benchmark to include the following additional calculations:

Phase I-A: 4 additional cases as outlined in the enclosed annex (M. Brady).

Purpose: assess the contribution of major and minor actinides as well as the major and minor fission products in the reduction of reactivity for burned PWR fuel.

Actions

* The results should be sent to M. Takano following the instructions provided in NEACRP-L-337.
* Participants are asked to check whether their results as displayed in the tables and graphs summarising the results of all participants (Parts 1-6) are correctly represented. It was noted that results not provided in the exact sequence as described in NEACRP-L-337 may in fact have been processed automatically, assuming the specified sequence. Results not conforming to that sequence should be resubmitted in the right format.
* Participants should provide additional written information on how they have carried out calculations, with the aim of shedding light on the summary tables and to facilitate interpretation of discrepancies. All deviations from the specification in NEACRP-L-337 must be reported. For example, participants should provide information as to which nuclides were resonance self shielded in their calculation and the method they have used. In addition as the composition of Zircalloy was not provided in the specification, participants should also specify the composition they have used. Note the incorrect specification of nu-bar if necessary submit corrected results.
* The results for the additional cases and revised results including comments must reach M. Takano by the end of August 1992.

* M. Takano agreed to revise tables and graphs with additional or new results and collect the comments, to form a first draft of the text. Participants willing to write part of the text should let the Secretariat know so that it can be coordinated. E. Whitesides and M. Brady have expressed their availability to write parts of it. The report should include some statement describing the validation and QA of the codes used. It was agreed that results not conforming to the specification will not be used to calculate averages or standard deviations because they would bias the conclusions.

Drafts of the final report will be sent to participants for comments and approval. Those who feel uncomfortable with the publishing of their results should say so and state whether their results should be withdrawn. Participants should refrain from publishing the results of other participants without their approval. The first draft will be circulated by the end of 1992. The status of the benchmark plus the proposed subsequent phases will be reported to the NSC on 3rd and 4th November 1992.

The final report containing the analysis and conclusions of Phase I and I-A is scheduled for the beginning of 1993.

The overall coordination of the publication for Phase I-A is carried out by M. Takano with support from the Secretariat.

Phase I-B: Isotopic Prediction (M. Brady)

Objective: to check the accuracy of depletion codes.

This part of the benchmark was renamed from Phase II-A to I-B. The purpose of Phase I is in fact to identify the origin of possible discrepancies in the different computational paths. I-A looks at discrepancies due to different cross section sets and their use. I-B looks at the other components: the isotopic compositions at different burnups. Predictions of isotopic compositions will be primarily dependent on the cross-section and fission yield data utilized in the calculations.

There was an extended discussion as to the best method for accomplishing the objective of Phase I-B. Published results for the chemical assay of spent fuel assemblies and fuel pins do exist. However there were concerns that calculations to model the experiments would be extremely complex even if all the necessary detailed parameters were included in the published reports, which is itself unlikely. In order to model these experiments with a large degree of precision could require complex codes and data to represent the fuel exposure (including in-core fuel movement) and the chemical separation and analysis. A suggestion was made to develop a simple calculational comparison problem that might be loosely tied to a published experiment. It was also noted that although prediction of isotopic composition is important, it is not the main objective of this study. M. Brady shall prepare a specification, based on experiments, which will satisfy the need of precision in the best possible way, but with necessary simplification due to lack of data. It will be either a calculation for a PWR assembly or fuel pin. The detailed specification and time schedule will be prepared in the autumn. The coordination of Phase I-B will be carried out by M. Brady.

ANNEX (NEACRP-L-337)

Part I-A Specification (M. Brady)

The purpose of this problem is to evaluate the contributions of major and minor actinides, and major and minor fission products in the reduction of reactivity for burned PWR fuel.

(1) Cases 10 and 1 should be calculated using the specification of NEACRP-L-337 with only the major actinides (i.e. delete Pu-242, Pu-238, Am-241, Am-243 and Np-237 from the previous case 4 and case 8 calculations).

(2) Using the fuel assembly and operating history descriptions on page 10 of Part I specification (NEACRP-L-337), calculate the isotopic inventory for fuel burned to 30 GWd/MTU and cooled to 1 yr. and 5 yr.

The number densities for minor fission products (all F.P. other than the 15 major F.P. previously selected) should be taken from this calculation - all other number densities should be taken from the previous specification This new subset of isotopics will be used in cases 12 and 13.

Cooling	MAJ ACT	ALL ACT	MAJ FP	ALL FP
1 yr	CASE 10	CASE 4	CASE 2	CASE 12
5 yr	CASE 11	CASE 8	CASE 6	CASE 13

* Only infinite multiplication factors will be calculated.

Phase II

Phase II aims at evaluating the effect of the axial burnup distribution. Both uniform and non-uniform burnup distributions will be considered as a function of initial enrichment, burnup, and cooling time in a two-dimensional infinite array of fuel pins and in a realistic geometry (generic 4 assembly truck cask). The final specification of this benchmark will be prepared by Makoto Takano of JAERI. The isotopic composition, including that associated with the axially distributed burnup, will be included in the problem specification and will be calculated by ORNL. A. Santamarina from Cadarache is providing the experimental axial profiles for a range of burnups from approximately 10 MWd/t to 60 MWd/t to be used in the calculation of the isotopic composition for the Phase II specification. The profiles are based on measurements of PWR fuel obtained from French utilities.

This phase will look primarily at axial end effects. These effects are particularly marked when fission products are taken into account. For low burnup this effect is difficult to see because of possible reactivity inversion burnup effects.

The investigation of radial burnup effects was also discussed and it was proposed that (1) the radial burnup profile is calculated, (2) its reactivity is estimated and (3) the radial migration of fission products is considered.

The preparation for Phase II has now been started.

Phase III

The possibility of a third phase was briefly discussed; in the course of the Phase II the need may be identified to investigate burned fuels other than for PWRs such as from BWRs or MOX fuels. A proposal for this further phase will be made to the NSC only if such a need is identified.

Discussion at the Third NSC Meeting

At the third meeting of the Nuclear Science Committee in November Dr. T. Asaoka , in charge of keeping the liaison between the group and the NSC, presented a status report concerning Phase I and I-A which included further results received after the June burnup credit meeting. An improved agreement among participants' results was observed.

The plan for Phase I-B and II were presented. The NSC approved both the extension of Phase I and the work outlined for Phase II.

Doubts were expressed however as to the need for investigating radial burnup effects and it was suggested that a real need for it should be assessed by one laboratory first before it is proposed to the full group.

Phase III should be started only if clear objectives have been identified and if there is a real interest in participating countries. In any case, such a proposal would be reviewed by the NSC first.

Further Developments

Phase I-B

The specifications for Phase I-B have now been finalized by M. Brady. Participants are asked to predict the isotopic composition of the fuel as a function of burnup for a simple pin cell; as in Phase I-A 12 actinides and 15 fission products are considered. These predictions will be compared against those obtained from fuel radiochemical analyses carried out at the Material Characterization Center of PNL(USA) for many of the isotopes considered in this benchmark.

The detailed specification was distributed as NEA/NSC/DOC(92)10. According to established deadlines a draft final report should be ready for June 1993. A status report will be provided to NSC at the next Meeting in May.

Phase II

The draft specification is being finalised and includes contributions from A. Santamarina, M. Brady and M. Takano. It is planned to distribute it to participants for comments at the beginning of 1993. A first summary of the results provided by participants will be presented at the next burnup credit meeting with the aim of resolving existing discrepancies and assessing the performance of the codes used on a realistic case. The overall coordinator of this work will be M. Takano from JAERI.

Next Meeting

Because of unforeseen delays in preparing the isotopic axial compositions for Phase II, it is anticipated that the meeting scheduled for beginning of June 1993, will be postponed to September 1993. At this meeting participants will compare and discuss the results of Phase II and resolve discrepancies observed among the different solutions provided.

The results of this phase will be reported to NSC in the autumn meeting of 1993.