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NUCLEAR SCIENCE COMMITTEE

Criticality Safety Studies

(Note by the Secretariat)

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Criticality Safety Studies

I. Introduction

1. The following activities have been carried out at NEA regarding out-of-pile criticality safety:

. Criticality of Nuclear Fuel Transportation/Storage Packages (1980-84)

. Criticality of Fuel Undergoing Dissolution (1986-90)

. Burnup Credit Criticality Benchmarks (1991-

2. A recent publication, "The Safety of the Nuclear Fuel Cycle", (1992) gives a general overview of the safety issues and procedures in Member countries; it includes also a chapter on regulatory issues.

3. An incident reporting system specific to significant events from the fuel cycle has been set up recently: FINAS (Fuel Incident Notification and Analysis System)

4. An international working group, reporting to the Nuclear Science Committee carries out the work programme in the specific field of criticality safety. The main effort concentrates on benchmark studies of interest to Member countries.

5. The participants to the present phase of the work programme are listed in Annex I.

II. Criticality Benchmarks

6. Several studies were carried out in which participants examined the ability of a variety of computational methods to accurately compute criticality for systems which have been measured to be experimentally critical.

- The first phase was oriented toward criticality safety of transport packages containing fissile material

- The second towards the criticality safety of dissolving fuel elements for fuel reprocessing and

- The third concentrates on the different aspects of burnup credit

The list of references to the publications summarizing the results is given as Annex II.

7. A procedure evolved from this work which has been shown to demonstrate whether a given computation method produces "valid" results. This procedure is expected to provide a basis for acceptance of computational results on an international basis by regulatory authorities through the comparison of methods used by various countries.

II.1 Criticality of Fuel Undergoing Dissolution

8. The results from the study using of eighteen experimental benchmarks were consolidated in a report. Three calculational benchmarks on criticality codes for dissolving fissile oxides in acids have also been published. A particular difficult problem proved to be the treatment of fuel double heterogeneities (solid fissile material surrounded by fissile material in solution). A reference calculational method for self-shielding effects of resonances was identified for this type of problem.

II.2 Burnup Credit Criticality Benchmarks

9. Burnup credit refers to including the predicted fuel composition (as a result of its utilisation in the reactor) in the evaluation of criticality safety limits in applications away from the reactor.

10. The standard approach used for the development and certification of spent fuel storage and transport packages is based on a fresh fuel assumption for the criticality safety analysis as it is the most reactive situation. There is a considerable reduction in reactivity if one takes credit for the burned state of the fuel. A higher payload can be achieved for instance for transportation packages thus diminishing the number of shipments which has advantages both from the economic and radiation protection point of view. In other words a balance is sought between reducing costs by improving plant and storage efficiency and optimal criticality safety by adopting realistic and well quantified safety margins and reducing hazards to populations by decreasing the number of spent fuel shipments.

11. The purpose of burnup credit studies is to demonstrate that appropriate procedures and techniques are available to ensure that the level of safety in current cask designs is not compromised.

12. The final objective is to produce state-of-the-art reports on the evaluation procedures for spent fuel system reactivity taking into account the isotopic composition and the non-uniform burning of the fuel.

Achievements:

13. A first benchmark investigating trends in criticality as a function of initial enrichment, burnup and decay time of a simple PWR spent fuel cell was completed. Safety margins were identified assuming different simplifying assumptions and in particular the effect of major and minor actinides and major and minor fission products. A satisfactory agreement among participants was achieved and the final report has been published.

14. The second benchmark addresses spent fuel isotopic inventories, another source of uncertainty in criticality calculations. Discrepancies found in a first iteration have been resolved now. The report will be published in the course of 1995.

15. The third benchmark concerns the effect of axial burnup in an infinite array of PWR pin cells. The results confirm that the reactivity effect due to axial burnup increases with burnup and cooling times. The final report will be published at the beginning of 1995.

16. An agreement was found on a benchmark with a realistic configuration such as PWR spent fuel assemblies in a cask geometry. This problem will be studied in the course of the coming year.

Future work:

17. Topics for future work will include:

- Evaluation of subcritical benchmarks:
  Nuclear data sets are often adjusted for k=1 and their reliability for k=0.95 needs to be verified.

- Burnup credit criticality in BWRs: No clear conclusion was drawn as to the advantage of burnup credit for transport purposes. The general feeling was that it is important for spent BWR fuel storage. A benchmark specification has been submitted.

- Burnup credit of MOX fuels

- Radial pin burnup effects

- Benchmark calculation of basic minimum critical values

III. **Other Activities in Support of Criticality Safety**

18. International criticality safety handbook/data base with criticality experiments:

This handbook will be the result of the compilation of data from experiments into a standard and the validation process of computer codes against them. Several countries are working on a national version of the handbook and there is now a general agreement that the international edition should combine these efforts to the benefit of the international community. The project is called "International Criticality Safety Benchmark Evaluation Project (ICSBEP)". The programme manager is D.Y. Chung (US DOE) and the project manager J.B. Briggs (INEL). In all there are approximately 60 participants.

US DOE has asked NEA to include this activity as an official activity of the NEA. The proposal was discussed at the NSC Bureau in December 1994 who appreciated the high interest of the data evaluated in the project and considered the involvement of the NEA-NSC appropriate. However, it was also agreed that a possible transfer to the NEA of the full responsibility for handbook updating could be discussed at the next NSC meeting following an evaluation of conditions and implications of such a transfer.

The handbook will be available both in paper and electronic form and its first edition will be published in May 1995 with the title: "International Handbook of Evaluated Criticality Safety Benchmark Experiments", NEA/NSC/DOC(95)03/I-VII.

19. Data base on isotopic inventories in spent fuel for criticality safety code validation:

An international data base of spent fuel assay, nuclide composition data with burnup history, for criticality safety benchmark studies was set up. This work is coordinated by JAERI the data base (SFCOMPCO) contains at present data from 13 LWRs (7 PWRs and 6 BWRs) located in Europe, Japan and USA. It will be supplemented with data from different countries so that it covers a wider scope; it is available to the international community.

20. Data base of basic quantities characterizing critical systems (cross sections, fission spectra, spectra of typical spent fuel systems) as needed by the most widely used criticality safety computer codes: objective: to facilitate comparisons and identify sources of discrepancy.

21. Experts' meeting on future needs for experiments in criticality safety, Las Vegas, September 1995:

Member countries' needs and concern of continued support for experiments and computational methods for criticality safety will be identified in particular in support of validation of computational methods required for advanced fuel cycles and recommendations for concrete actions formulated.

IV. **Meetings, Conferences**

22. The group meets once per year to discuss and monitor progress in the international problem exercises and benchmarks and to define a work programme for the following year.

- The next meeting will be held from 27th to 29th September 1995 in Las Vegas. It will be held just after the ICNC'95 Conference and the Expert meeting on future needs in Criticality Experiments.

- A seminar on SCALE-4 and Related Modular Systems for the Evaluation of Nuclear Facilities and Package Design Featuring Criticality, Shielding and Heat Transfer Capabilities was organised by NEA in 1992

23. A series of inferences in criticality safety were in Los Alamos (1981), Valduc/Dijon (1985), Tokyo (1988) and Oxford:

- Fourth International Conference on Nuclear Criticality Safety - ICNC'91 Oxford, 9th to 13th September 1991

  It was attended by 170 specialists from 26 countries and 2 international organisations, including for the first time experts from Russia.

24. The next one will be the

- Fifth International Conference on Nuclear Criticality Safety - ICNC'95 to be held in Albuquerque, New Mexico, from 18th to 22nd September 1995.

- A conference on the Safety of the Nuclear Fuel Cycle scheduled for October 1995 in Japan is co-sponsored by the NEA.

ANNEX I

List of Working Group Members

NSC Burnup Credit Criticality Benchmark Meeting

OECD, Chateau de la Muette, 11th to 13th July 1994

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* sent apologies for being unable to attend

ANNEX II

Bibliography of Work Carried Out

Criticality of Fuel Transport/Storage Packages

NEACRP-L-326
Standard Problem Exercise on Criticality Codes for Spent LWR Fuel Transport Containers. (CSNI Report No. 71) May 1982

NEACRP-L-327
Standard Problem Exercise on Criticality Codes for Large Arrays of Packages of Fissile Materials. (Report No. 78) August 1984

Criticality of Fuel in Dissolution

NEACRP-A-1029
Understanding the Effect of a Double-heterogeneity on Criticality Calculations and a Method for the Realistic Treatment of the Physics of this Problem, July 1989
A. Santamarina, H.J. Smith (CEA - Cadarache)

NEACRP-L- 306
Standard Problem Exercise on Criticality Codes for Dissolving Fissile Oxides in Acids. A Report of the NEACRP Criticality Working Group. (Editor: G.E. Whitesides), April 1990

NEACRP-L-320.
Analysis of the OECD/NEACRP Problem No. 20 on International Criticality Codes for Fuel Pellets in Fissile Solution, December 1990
A. Santamarina, H.J. Smith,

NEACRP-L-325
Analysis of the International Criticality Benchmark No. 19 of a Realistic Fuel Dissolver, January 1991
H.J. Smith, A. Santamarina,

NEACRP Standard Problem Exercise on Criticality Codes for Dissolving Fissile Oxides in Acids. A reference Method for Treating the Fuel Double Heterogeneity, April 1990, Proceedings of PHYSOR'90 Conference, Marseille
A. Santamarina, H.J. Smith, G.E. Whitesides

Evaluation and Validation of Criticality Codes for Fuel Dissolver Calculations, September 1991, Proceedings of ICNC'91 Conference, Oxford
A. Santamarina, H. Smith, G.E. Whitesides

Burnup Credit Criticality

NEACRP-L- 337
Burnup-Credit Criticality Benchmark
Phase I-A. Simple PWR Spent Fuel Cell (Problem Specification)
Makoto TAKANO (JAERI), (Michaele BRADY (ORNL))

NSC/DOC(93)- 22
Burnup Credit Criticality Benchmark, Final Results of Phase I-A
January 1994
JAERI-M-94-003
Makoto TAKANO (JAERI)

NSC/DOC(93)- 15
Burnup Credit Criticality Benchmark, Phase II-A: Effect of Axial Burnup Profile (Infinite fuel pin array)
Makoto Takano (JAERI), Michaele Brady (SNL), Alain Santamarina (CEA)
June 1993

NSC/DOC(92)- 10
Burnup-Credit Criticality Benchmark, Part I-B. Isotopic Prediction (Problem Specification)
Draft 30 November 1992
Michaele C. Brady

A report on these activities has been presented by the Chairman of the group (G.E. Whitesides) at the different SAGSTRAM Conferences.

ICSBEP Handbook

NSC/DOC(95)-3
International Handbook on Evaluated Criticality Safety Benchmark Experiments I. Plutonium Systems. II. Highly Enriched Uranium Systems. III. Intermediate and Mixed Enrichment Uranium Systems. IV. Low Enriche Uranium Systems. V. Uranium 233 Systems. VI. Mixed Plutonium Uranium Systems, Dae Y. Chung (DoE), J. Blair Briggs, Lori Scott and June Williams (INEL), May 1995