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NUCLEAR ENERGY AGENCY

STEERING COMMITTEE
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NUCLEAR SCIENCE COMMITTEE

2nd Meeting of the

WORKING PARTY ON PHYSICS OF PLUTONIUM RECYCLING (WPPR)

Le Seine Saint-Germain
12 boulevard des Iles, 92130 Issy les Moulineaux
21-23 March 1994

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FOR TECHNICAL REASONS TABLES AND GRAPHS ARE NOT AVAILABLE ON OLIS

NEA Nuclear Science Committee (NEANSC)
2nd Meeting of the
WORKING PARTY ON PHYSICS OF PLUTONIUM RECYCLING (WPPR)
Le Seine Saint-Germain
12 boulevard des Iles, 92130 Issy les Moulineaux
(21-23 March 1994)

SUMMARY

I. Meeting Organisation

The meeting was structured into two parts: the first was devoted to the benchmark studies, while the second was the WPPR plenary and executive session.

The detailed agenda as adopted is given as Annex A.

II. Participants

The second meeting of the Working Party on Physics of Plutonium Recycling (WPPR) was chaired by M. Salvatores, CEA, France and was attended by 28 participants from 10 countries and 2 international organisations. In all more than 40 persons have contributed to the studies of the Working Party. The list of participants and contributors is provided in Annex B.

III. Objectives

The present objective is to finalize a state-of-the-art report on the scientific issues related to plutonium recycling by early 1995.

The objectives of this meeting were to discuss a first draft of the report and the results from the benchmark studies launched at the first WPPR meeting.

IV. Other Activities related to WPPR

Since the setting up of the WPPR, two international activities were initiated:

- NEA NDC has set up in March 1994 an Expert Group on plutonium management with the objective of producing a document addressing background for strategic issues. A first draft is expected for October 1994. The work of the WPPR should form the technical-scientific more strategic views. Work of the two groups is well coordinated and they should achieve their objectives in phase.
- The IAEA has called a consultancy meeting in January 1994 in which long term options for plutonium disposition were discussed. Standard reactor systems are outside the scope of this activity at least for the near future. A meeting is planned in Obninsk for November 1994

devoted to "advanced" type systems for handling plutonium. There is practically no overlap between this activity and the one of WPPR, but they are complementary.

V. Benchmark Sessions

The first two days of the meeting were devoted specifically to present, interpret and discuss the results from the different benchmarks designed to clarify in depth some of the most important physics issues in plutonium recycling.

Fast Reactors

During the first day the objectives of the benchmarks relative to plutonium recycling in fast reactors were presented and reviewed by D. Wade; the results of the benchmark on the configuration of a plutonium-burner MOX-fuelled fast reactor (600 MWe) were first presented. Four organisations have participated: ANL, CEA, PNC and TOSHIBA (only BOL case). It is expected that a contribution from Russia will be provided through the IAEA, as well as other possible contributions for the beginning of life calculation. The results presented had undergone some iterations and problems with basic data and misinterpretations of the specification have been solved.

It was noted that the agreement on spectral indices calculations has improved considerably over the last 10-15 years. The ratio of sodium void coefficient and Doppler coefficient is about 2 for this configuration at the beginning of cycle, the spread in the sodium void coefficient at the end of cycle being somewhat larger than expected, and the transport effects need to be determined.

The second benchmark concerns a metal fuelled fast reactor. It consists of three cases starting with a simple physics benchmark and progressing to benchmarks of higher complexity. The cases considered are the following:

- Metal-fuelled burner core benchmark (initial loading) (breeding ratio approximately equal to 0.5)
- Metal-fuelled once-through burner core benchmark (breeding ratio approximately equal to 0.5)
- Metal-fuelled multiple recycle burner core benchmark (with 3 subcases for breeding ratio = 0.5, 0.75, 1.0)

Four contributions to case 1 were submitted : ANL, CEA, PNC and a European one.

One benchmark result for case 2 was completed and two more were in progress. Case 3 is more complex and will require a few months more for completion.

The radiotoxicity of the source term is one of the main physical parameters for which the WP will provide a comparative analysis, or what is equivalent, the isotopic inventories for the different recycle options.

Some discrepancies were observed between some of the solutions submitted, the causes of which were identified. Revised results will be submitted after the meeting.

The values of the reactivity coefficients (sodium void and Doppler coefficient) are relatively small. The sodium void coefficient is approximately zero due to high leakage. The Doppler coefficient is also small in absolute value, but still negative.

LWR reactors

During the second day the benchmark results concerning recycling of plutonium in LWRs were presented and discussed. There are two cases : one looking at the first recycle ("better" quality Pu), the other related to a fuel composition corresponding to the fifth recycle ("dirty" Pu). A third benchmark addresses the void reactivity coefficient. The rationale behind these benchmarks was introduced by H. Kuesters , G. Schlosser and P. D'hondt. These benchmarks address the question as to how many recycles are possible, with what accuracy one can calculate the physical parameters and what burnup can be achieved.

A very first intercomparison with results obtained about 10 years ago when a similar benchmark was performed on Pu tight lattice LWRs shows that the spread of the different results has been reduced significantly, even if discrepancies are still found

In the case of "dirty Pu", the BOL spread in k-infinity is around 4% while that for EOL is about 5%. Several questions were addressed:

- self-shielding of even Pu isotopes (in particular Pu-242)
- self-shielding treatment of unresolved resonance range (in particular in Monte Carlo codes)
- fission product representation
- the treatment of the (n,2n) reaction
- which fission yield data sets were used
- which fission spectra were used, were they burnup dependent?
- were the lumped fission products for the actual case ?

Some of these questions were answered through a questionnaire at the meeting.

Results will be grouped by data base used and method. Significant features will be underlined. For example, the self shielding effect should be compared using VIM, MVP and the modified MCNP version using the SESH module in the unresolved resonance region.

Void coefficient

Another benchmark of the WPPR (Benchmark 2) was devoted to the question of limits of Pu enrichment/content to avoid a positive void coefficient. Results of pin cell calculations show clearly that for total voiding the limit will be in the range of 8-9% Pufiss respective 12-13% Pu. With increasing Pu content the positive reactivity contributions of Pu240 and Pu242 compensate the negative void coefficient contribution of U238 being dominant in U lattices and MOX lattices up to the mentioned Pu contents.

VIPO-type configurations of a MOX area which is to be voided totally, but coupled with an unvoided UOX area surrounding the MOX were also calculated. Small positive reactivity effects had been calculated by the WPPR for much lower Pu concentrations caused by MOX-voiding. Such effects are found for comparable arrangements by voiding a low enriched UOX area, too. Studies show that the calculated reactivity effect comes from the rebalancing of reactor rates to the external UOX zone: the central (voided) zone becomes more transparent to neutrons; thus the neutronic behaviour of the whole lattice approaches that of an infinite medium of unvoided UOX fuel.

In the conclusive discussion it was agreed to revise a number of results (both participants as well as result analyzers). This should be carried out within short time so that problem coordinators will be able to provide revised tables and graphs by May 1994. This should lead to a reduction of the spread of results, the comparison of self shielding effects and the understanding of the physics underlying the VIPO experiment void coefficient.

The list of papers presented and distributed at the meeting are provided in Annex C.

VI. Plenary session

The third day was devoted to the plenary session. Actions from the previous meeting were reported. All actions had been carried out (see Annex D). The draft chapters of the state-of-the-art report were presented and discussed, the presentation in the interim report was agreed, and finally the plan on further work on the benchmarks was outlined.

The schedule for the work programme was revised and is shown in Annex E. A number of actions were decided which should lead to completion of the report by early 1995. These are shown in Annex F.

Outline of the Report

It was decided that the state-of-the-art report will be published in two volumes. The first discusses the different issues as outlined in the interim report. This volume will contain information about the benchmarks in a summary form only. The second volume will be devoted exclusively to the analysis of benchmark results including discussions and recommendations.

Presentation of GLOBAL'95

It was agreed that the results of this report could be the subject for a presentation at GLOBAL'95 conference in Versailles, September 1995.

Next Meeting

The next meeting is scheduled for 22-24 November 1994 and will be held at OECD in Paris.

ANNEX A

ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

Nuclear Energy Agency Nuclear Science Committee (NEANSC)

2nd Meeting of the

WORKING PARTY ON PHYSICS OF PLUTONIUM RECYCLING (WPPR)

OECD/NEA Le Saint-Germain
12 Boulevard des Iles
7th floor
92130 Issy les Moulineaux

21-23 March 1994

AGENDA

FAST REACTOR BENCHMARKS

* 21 MARCH 1994

10:00 am

1. Introductory Remarks (Salvatorese, Sartori)
Introduction of Participants
2. Review and Approval of the Agenda
3. Other Activities related to the work of the WPPR
4. Fast Reactor Benchmarks
 - a) Objectives of Benchmarks (Wade)
 - b) Configuration of a Pu-Burner Fast Reactor (500 MWt)
NSC/DOC(93)-18 (revision 1)
 - (i) Summary Review of Calculations (Wade)
 - (ii) Presentation of Results by Participants
 - (iii) Contribution to interim report, discussion.
 - c) Metal-fuelled Fast Reactor
NSC/DOC(93)-24
 - (i) Summary Review of Calculations (Wade)
 - (ii) Presentation of Results by Participants
 - (iii) Contribution to interim report, discussion
5. Review of lessons learned from recycling Pu in fast reactors
General discussion
6. Preliminary Discussion of Schedule

ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

Nuclear Energy Agency Nuclear Science Committee (NEANSC)

2nd Meeting of the

WORKING PARTY ON PHYSICS OF PLUTONIUM RECYCLING (WPPR)

OECD/NEA Le Saint-Germain
12 Boulevard des Iles
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92130 Issy les Moulineaux

21-23 March 1994

AGENDA (Continuation)

PWR BENCHMARKS

* 22 March 1994

9:00 am

7. Introductory Remarks (Salvatorese, Sartori)
Introduction of Participants
8. Pressurized Water Reactors
 - a) Objectives of Benchmarks (Kuesters, Schlosser)
 - b) Plutonium Recycling in PWRs (Kuesters, Schlosser, Vergnes)
- Benchmark with Dirty Plutonium
NSC/DOC(93)-19
(Revision of chadding: 25 Nov. 1993)
 - (i) Summary Review of Calculations (Lutz)
 - (ii) Presentation of Results by Participants
 - (iii) Contribution to interim report, discussion
 - c) void reactivity effect in MOX lattices (PWR)
NSC/DOC(93)-20
 - (i) Objective of Benchmark (D'André)
 - (ii) Summary Review of Calculations (Lutz)
 - (iii) Presentation of Results by Participants
 - (iv) Contribution to interim report, discussion
9. Review of lessons learned from recycling Pu in PWRs
General Discussion

ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

Nuclear Energy Agency Nuclear Science Committee (NEANSC)

End Meeting of the

WORKING PARTY ON PHYSICS OF PLUTONIUM RECYCLING (WPPR)

CECD/NEA Le Saint-Germain
12 boulevard des Illes
7th floor
92130 Issy les Moulinsaux

21-23 March 1994

AGENDA (Continuation)

WPPR PLEIARY SESSION

* 23 March 1994

8:30 am

10. Chairman's Introductory Remarks (Salvatores);
Introduction of Participants
11. Review and Approval of the Agenda
12. Status of Actions from the Previous Meeting
13. Summary of the Benchmark Studies (Wade, Kuesters),
[PWR lattices void coefficient (Hesketh)]
14. First Draft of the State-of-the-Art Report
 - a) review of introductory chapter (Salvatores)
 - b) review of chapter on the fast reactor benchmarks (Wade)
 - c) review of chapter on the PWR benchmarks (Kuesters, Schlosser)
 - d) review of chapter on advanced converters (Jones)
 - e) review of chapter on plutonium fuel without uranium (Ikegami)
 - f) review of chapter on uranium recycling (Jones)
 - g) structure of the report, homogenisation of styles,
recommendations to NSC, annexes
15. Relation with activities of NEA-NDC and IAEA Working Group
16. Future Workplan:
 - a) programme of work for next round of comparisons
 - b) distribution of tasks
 - c) presentation at GLOBAL'95
17. a) Time schedule
b) distribution of tasks
c) Arrangements for Next Meeting(s)
18. Closing (13:00 - 14:00)

ANNEX B

AGENCE DE L'OCDE
 POUR L'ENERGIE NUCLEAIRE
 OECD NUCLEAR ENERGY AGENCY

23 March 1994

List of Participants in the

Second Meeting of the

NSC Working Party on the Physics of Plutonium Recycling

OECD/NEA, Issy les Moulineaux

21-23 March 1994

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ANNEX C

LIST OF PAPERS DISTRIBUTED AT THE SECOND WPFR MEETING

NOTE: All papers distributed have to be considered as work in progress. Results appearing in them cannot be cited without explicit authorisation by the originator of the results. The same is valid for the draft chapters of the report. The report will undergo approval by the Members before it is published.

General papers and other Background Papers

H. Sekimoto: "Physics of Future Equilibrium State of Nuclear Energy Utilisation", Proc. Intl. Conf. on Reactor Physics and Reactor Computations, Tel-Aviv, January 23-26, 1994

H. Takano, H. Akie, M. Banda, T. Hirakawa, K. Nakamura, K. Hirota, Y. Kamishima, Y. Tanaka, H. Takahashi, K. Kaneko
"A Concept of Self-Completed Fuel Cycle Based on Lead-Cooled Nitride Fuel Fast Reactors", ICENES'93 Conference, Makuhari

H. Akie, T. Marumura, H. Takano, S. Matsumura: "A New Concept of Once-through Burning for Nuclear Waste Plutonium", ICENES'93 Conference, Makuhari

V. M. Mikhailov, V. M. Murogov, V. S. Kagtamanian, K. S. Pabotnov, V. Ya. Rudneva
M. F. Troysnov: "Plutonium in Nuclear Power Industry", IAEA January 1994.

Benchmark Specifications:

J. C. Garnier, T. Ikegami: "WPFR: Proposal for a Benchmark Configuration of a Pu-Burner Fast Reactor (600 MWe)", NEA/NSC/DOC(93)18 Rev.1 November 1993

D. C. Wade: "WPFR: Specification for Metal-Fuelled Fast Reactor Benchmarks" NEA/NSC/DOC(93)24, October 1993
Clarifications to this specifications:
Letters by D. C. Wade, 13 and 18 January 1994.

J. Veronesi, E. M. Wise, G. Schlosser, H. Kuesters:
"WPFR: Benchmark Specification for Pu Recycling in FWRs" NEA/NSC/DOC(93)19, 31 August 1993
Corrections to plutonium isotopes and clarifications
Letter: E. Sartori, 13 December 1993

M. Maldague, G. Minsart: "WPFR: Void Coefficient Benchmark: A Proposal for a Computational Exercise on Void Reactivity Effect in MOX Lattices", NEA/NSC/DOC(93)20, 31 August 1993.

Contributions to Benchmarks and Presentation:

Fast Reactor Benchmarks

D. C. Wade: "Overview of Oxide Fast Reactor Results"

G. Palmicotti: "ANL Solution of the Oxide Fuel Benchmark Configuration of a Pu-Burner Fast Reactor"

J. C. Garnier, F. Varaine: "Neutron Physics Calculation of a Pu-Burner Fast Reactor (600 MWe) + revision"

T. Ikegami, T. Yamamoto, S. Ohki: "FNC's Results for the Benchmark on the MOX Fueled Fast Reactor Core"

M. Kawashima, M. Yamaka: "A Benchmark Calculation of a Pu-Burner Fast Reactor (600 MWe)"

D. C. Wade: "Overview of Metal Fast Reactor Results"

"Draft of ANL solution of the first two parts of the three part metal fuelled benchmark"

G. Rimpault, J. Dasilva, F. Smith: "European Neutronic Calculations for the Metal Fuelled Fast Reactor Benchmark"

T. Yamamoto: "A Preliminary Result on the Metal-Fueled Fast Reactor Benchmarks"

Thermal Reactor Benchmarks

D. Lutz: "Overview of Results from the Benchmark on Pu Recycling in PWR: Tables and Graphs"

H. Akie, H. Takano: "Results of the Benchmark for Plutonium Recycling in PWR"

A. Pulli, A. Kolmayer: "Recycling of Pu in a PWR"

P. Marinbeau, P. Barbrault, J. Veronesi: "Recycling of Pu in FWRs"

K. Ishii, H. Maruyama: "Benchmark Calculation of Fuel Assembly Code VMCNT for PWR-MOX lattice"

K. Reaketh: "Results of BNWL Analysis of FWR Reactivity Benchmark"

Void Reactivity Coefficient:

D. Lutz: "Overview of Results from the Void Reactivity Coefficient Benchmark Tables and Graphs"

G. Minsart: "Calculational Scheme and Results"

P. A. Landeyro: "Calculational Method and Results"

H. Takano, H. Akie, Y. Uehara, K. Ishii, H. Maruyama: "Benchmarks for Pu Recycling and Void Reactivity Effect in MOX-PWRs"

H. Takano, H. Akie: "Results of the Void Coefficient Benchmark"

Draft Chapters for the WPPR Report:

- M. Salvatores: "General Introduction"
 H. Kussters, G. Schliesser: "Pu Recycling in LWRs"
 D.C. Wade: "Pu Production/Burning in Fast Reactors"
 Metal Fuel/Fuel Cycle
 General Overview of Physics of Pu Recycling: Situation, Question
 Issues, Incentives and Costs
 Macrosystem Viewpoint: Once Through Cycle, Recycle
 Focus on Fast Reactor Part of Report (Viewgraphs)
- T. Ikegami, M. Koinumi: "Pu Fuel Without It" (revision)
 R.T. Jones: "Recycling of Pu in Advanced Converter Reactors"
 R.T. Jones: "The Use of Recycled Uranium"
- Actions: -----
 P. D'handt: WPPR-Action 6 (on C/E values about VENUS experiments on
 moderator density coefficients)

ANNEX D

Status of WPPR Actions (21.III.1994)

COMPLETED ACTIONS

1. Secretariat
Clarified with NSC the participation of non-Member countries in WPPR work and meetings. (Participation in the benchmark studies are welcome contacts with IAEA on the subject should be maintained)
2. Kuesters, Schlosser, Salvatores:
Clearance for wider distribution of benchmark specification for MOX recycling in IRRs.
(clearance given)
3. Kuesters, Schlosser:
Provide by May 1993 the benchmark specification concerning MOX recycling first phase (cell with bad quality Pu). In a second phase, the specifications for multiple MOX recycling will be prepared by end of summer 1993.
(cladding composition was corrected - new specification sent out 25.XI.93)
4. D'Hondt:
Extend VISO void coefficient benchmark, specify calculational options for distribution by April 1993.
(benchmark specification has been distributed)
5. The documentation of available Kritz experiments has been distributed to members for temperature coefficient investigations.
6. D'Hondt
Send to Secretariat for distribution relevant material on C/E values published in Japan about the VENUS experiments on moderator density coefficients
(distribution at 2nd meeting)
9. Wada:
Prepare specification on FR metal fuel benchmark by the end of May.
(specification and draft chapter for Pu recycling in FRs has been distributed.)
9. Ikegami, Salvatores, Garnier:
Provide specification of FR MOX fuel benchmark by the end of May 1993.
(benchmark specification and revision 1 has been distributed)
12. Kuesters
Provide to Salvatores report on German experience on Pu in cerium matrix (input provided to Ikegami)
14. Members
Provide input from national experience in U recycling to Jones
16. Members
Provide input from national experience on Pu recycling in advanced converters

Completed action on COORDINATION and DRAFTS

7. Wada
Coordinated the work on Pu recycling in FRs
draft (analysis of results: R. Hill and G. Palmiotti)
 10. Wada
Coordinated the work on Pu recycling in FRs
draft (analysis of results: R. Hill and G. Palmiotti)
 11. Ikegami, Salvatores
Coordinated the work on Pu without U in consultation with WPPR members
draft
 13. Jones
Coordinated U recycling work
draft
 15. Coordinated Pu recycling in advanced converter reactors
draft
 17. Coordinators
Collected results of benchmarks
* Results for Fast reactors sent to R. Hill, ANL, USA
* Results for PWRs should sent to D. Lutz, IRE, Germany
 18. Salvatores
Provided first draft of introduction to interim report
 19. Relevant bibliographic references and abstracts for PU and U recycling have been distributed to Members
 20. Secretariat
Distributed draft benchmark reports on benchmark results
(at second meeting)
 22. Distribution of:
Terms of reference of NSC Working Parties
NSC and NSC Programme of Work (93/94)
Joint NEA statement on partitioning and transmutation
Information on activities on fuel behaviour
to Members.
- ACTIONS TO BE COMPLETED
21. Secretariat, Salvatores
Coordinate preparation of interim report; prepare proposal for further work

Annex ETime schedule for preparing interim and final reports

Status 23.III.94 - Completed actions :

- | | |
|---|---------------------|
| - Benchmark specifications: | |
| . MOX recycling in PWRs | May 1993 |
| . Multiple MOX recycling | summer 1993 |
| . Void coefficient benchmark for MOX in LWR | May 1993 |
| . metal fuel FR | May 1993 |
| . MOX fuel FR | May 1993 |
| - Distribution to participants by the Secretariat | June 1993 |
| - Benchmark results | February 1994 |
| - Draft of General introduction to report | February 1994 |
| - Draft report for each objective | February 1994 |
| - Combined draft report | March 1994 |
| - First Benchmark meeting | 21-22 March 1994 |
| - Second WPPR meeting | 23 March 1994 |
| <hr/> | |
| - Interim WPPR report | May 1994 |
| - Presentation of status of WPPR to NSC meeting | May 1994 |
| - Revised Benchmark Results for LWR and FR
and Analysis | September 1994 |
| - Distribution of Revised Benchmark Results and
Analysis | October 1994 |
| - Third WPPR meeting: final discussion on revised
benchmarks and state-of-the-art report | 22-24 November 1994 |
| - Integrate Benchmarks into Report - Editing of report
(including Annexes, if any) | January 1995 |
| - Distribution of Report to Members | March 1995 |
| - Final Editing/Printing of the Report | March 1995 |

Annex FActions from the 2nd WPPR MeetingREPORT

- Salvatores, Wade: Specify in report the issue of the activity/radiotoxicity of the source term as a parameter (but acknowledge the controversial aspect with respect to residual risk)
- Authors of Chapters : Revise interim chapters (by end of April)
- Authors of Chapters : Send text on computer readable form (diskettes, e-mail) to secretariat

FAST BENCHMARKS

- Participants : Use a common hazard factor for homogeneity and easy comparison.
- All Participants: Provide Beginning-Of-Life solutions for Metal-fueled and Oxide-fuel Benchmarks to Wade (by end of July)
- Participants : Estimate transport effect corrections in fast reactor benchmarks
- Wade : Underline the issues for the FRMOX benchmark.
Garnier : Originators should provide in return their comments
Ikagami
- Wade : Specify rationale for the choice of the metal core benchmark configurations (limit in Pu content, Na void versus reactivity swing, etc.)
- Participants : Provide complementary results on FR metal fuel benchmarks phase 2 and 3 by end of July 1994.
- Rinejski : Take action to ensure benchmark contributions on fast reactors from the Obninsk group (by end of July)

THERMAL REACTORS

- Participants : Provide Lutz with information, whether further results are submitted (new or corrections) or whether results will be withdrawn (by beginning of April 1994)
- Participants : Provide Lutz with analysis of results and comments that might explain discrepancies, etc. (by end of April)

- Participants : Compare averaged cross sections calculated with Monte Carlo (MCNP, MVP, VIM) to estimate the resonance shielding factors for MOX in PWRs (or shielding effects on k-infinity)
- Secretariat : Collect from Lutz revised tables and graphs (PostScript files) for distribution
- Coordinators : Group results by type of evaluated data library used or by code to help analysis (e.g. unresolved resonance treatment in MCNP)
- Bernnat : set up a task group addressing the physics of the
Cathalau VIPO type void effect: (by end of April)
Finck
Deramaix
Hesketh
Schlosser