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CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

STEERING COMMITTEE
FOR NUCLEAR ENERGY

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NUCLEAR SCIENCE COMMITTEE

SECOND MEETING OF THE
TASK FORCE ON SCIENTIFIC ISSUES IN FUEL BEHAVIOUR

7th November 1994
IFE/OECD-Halden Reactor Project, Halden, Norway

018370

Task Force on Scientific Issues in Fuel BehaviourSummary of the Second Meeting**I. Welcome - Technical Visits**

The chairman (K. Bendiksen) and the HRP Manager (C. Vitanza) welcomed the participants to the meeting.

The chairman gave a brief introduction of the activities carried out at the hosting institute (IFE) in general and of the OECD-Halden Project in particular. A visit to the Halden reactor and to the laboratories was organised by C. Vitanza. The preparation of rigs for the forthcoming experiments was shown and explained to participants.

A reminder was given as to the objectives and work programme of the Task Force.

II. Adoption of the Agenda/Introduction of New Participants

The agenda was adopted without modifications (Annex 1).

The following Members apologised for not being able to attend: P. Chantoin, F. Iglesias and N. Lassmann. T. Furuta and J.F. Marin sent replacements to represent them at the meeting: J. Nakamura and C. Lemaignan. The list of participants is given in Annex 2.

III. Report to NSC**III.1 Overall Structure**

A revised draft, including the previously missing chapters was distributed to participants.

A new overall structure was adopted, in which the specific issues are presented in a more logical order than in the draft. The new structure is given in Annex 3.

The issue of high burnup fuel behaviour in transient conditions was discussed and it was decided not to remove it from the report but to place it in Annex B. In fact,

not all transients lead to geometry loss and many occur in more normal operating conditions

the phenomena discussed in the report are relevant for transient conditions

the specific issue of reactivity initiated accidents (RIA) of particular importance to fuel behaviour will be covered by the CSNI/PWG2. This activity will be explicitly referred to in the report.

the borderline with safety will be explained.

It was agreed that coordinators and authors for each issue should not appear explicitly after the section headings, but that contributions and the roles played by each are described at the beginning of the report. The objective is to present it as a consensus view of the group.

III.2 Chapter by Chapter Discussion

Chapter 1: Introduction, needs to reflect the re-arrangements of the order in which issues should appear. In addition a paragraph should be added explaining why we are addressing these issues, what is the common thread.

Chapter 2: Ongoing Activities, should have an introduction describing the purpose of the chapter and a statement that the list of activities is not intended to be comprehensive but rather a guide for establishing cooperation and coordination. The list of activities must be thoroughly verified and agreed on with experts in the countries. It was suggested that this chapter be placed after chapter 3.

For **Chapter 3: Scientific Issues and Modelling Aspects**, the following was agreed:

in general, each section covering a specific issue or phenomenon should include a few sentences at the beginning explaining why it is so important for fuel behaviour modelling. Each member was asked to review all the sections again and to provide comments to the subject coordinators.

- **Thermal Analysis**

It was suggested that a general warning is added to the extent that one cannot separate the thermal conductivity of gap and fuel and that data that are equitable in this respect need to be looked at in model validation.

It was suggested that the relevance of the power profile in the rod should be mentioned specifically (It can be 3 times as high at the rim)

H. Kwast presented a fundamental approach used at ECN for calculating thermal conductivity and its dependence on porosity. The section in the report insists already that "porosity correction factors will always remain a source of uncertainty and need permanent attention" H. Kwast should contact K. Lassmann if further changes to text are considered important.

It was suggested that the alternative formulation for the phonon component of the thermal conductivity is at least mentioned as it seems to be particularly useful for additives (arctan formulation - see panel on thermal conductivity at Windermere meeting).

- **Fission Gas Release**

An introductory part needs to be added describing the origin of fission gas and why this issue is so important.

Some editorial changes and rephrasing of sentences were suggested.

- **Fission Gas Swelling**

A few sentences describing why this issue is a concern should be added. The composition of the gas in the gap at high burnup should be mentioned.

- **Stress Corrosion Cracking**

No changes were proposed to this section.

- **Constitutive Equations**

These equations have many parameters, which are material dependent. The expected difficulties in developing this issue should be mentioned.

Adding of some statements as to how to deal with complexity was suggested. In particular reference could be made to the discussion at Wandermere on the 1.5-D versus 3-D approach.

G. Valli suggested to mention explicitly work carried out on niobium alloys; he volunteered to submit to H. Lassmann a draft text in this respect.

- **Water Chemistry**

An introductory part needs to be added. It should be mentioned explicitly that this section is a summary of a meeting organised by the IAEA. The effect of adding zinc should be mentioned and some rephrasing is still required.

- **Hydrogen Measurement Techniques (in cladding)**

Some additions will be made by H. Kwast.

- **Failed Fuel Behaviour**

Only minor editing was proposed.

- **Spent Fuel - Long term Behaviour**

An introductory statement should be added. Some minor additions and rephrasing are required.

- Quality Assurance Process for New Integral Experiments

To this section a text will be added stressing the importance of code validation and verification. The present text is rather inhomogeneous as it consists of two parts written by two authors. It was suggested that fuel irradiation should not be confined to MTR reactors but should possibly be broadened to other types of irradiations i.e. power reactors. It was felt that not too much weight should be given to re-fabricated fuels and the section on good usage of monitoring is excessively detailed. It was agreed that the title should be changed to : QA Process for Experimental Data Analyses to reflect the computer code validation aspects.

Because of reordering, this chapter will be labelled **Chapter 2**.

Chapter 4: Priorities for Future Work, consists of three parts. The first one describes activities identified as having high priority but which are carried out within the programme of work of the IAEA. The purpose is to make sure that duplication does not take place. The second identifies some basic underlying phenomena of fuel behaviour that should receive high attention in the research programmes of Member countries. The third part identifies the means of cooperation, namely proposals emerging from specific needs in Member countries and discussions within the group. These are:

- the setting up of a data base of experiments for fuel rod modelling purposes, and
- benchmarking and validation of modelling codes through international exercises.

Chapter 5: Recommendations and Conclusions, specifies more precisely what should be done. A first recommendation has already been pursued after approval by the NSC. It consisted in preparing a review of well characterized and instrumented experiments on fuel behaviour and identification of those that should form a first basis for establishing an international data base of experimental results. This aspect was discussed in more detail in part IV of the agenda. The chapter includes also recommendations from the review report itself, namely that of carrying out a pilot study on one important experiment from the Halden Reactor Project in order to establish the format of the data base, and to estimate the effort required for establishing it. International code comparisons, including validation against experiments, an activity strongly linked to the establishment of the data base, were recognised as important.

It was also recommended that countries and organisations make special research efforts that would lead to a better understanding of:

- thermal conductivity,
- fission gas release,
- fission product swelling
- modelling of thermo-mechanical behaviour; constitutive equations.

Topical meetings covering these issues should be organised by NEA/NSC in coordination with the IAEA.

Restructuring and re-arrangements of Chapter 4 and 5 was suggested.

III.3 Approval of Report

The report in the draft status as presented at the meeting was not ready for approval. The discussion was therefore postponed to topic V. Time Schedule.

IV. Special Recommendations and Initiatives

This session aimed at identifying initiatives and actions to meet the objective of a better understanding of the basic underlying phenomena in fuel behaviour. The proposals are included in chapters 4 and 5 of the report.

J.A. Turnbull reported on the:

- Status of compilation and review of an experiment data base

A draft report was presented and the scope and objectives of this report, commissioned by NSC, explained. The report covers well characterized and instrumented experiments on fuel behaviour, covering mostly those from the OECD/Halden Reactor Project, but also from Risoe and Studsvik. J.A. Turnbull was commended for this excellent piece of work. Members were asked to provide final comments by 1st of December.

The group then discussed the proposal of setting up a data base with experiments covering in a comprehensive way all relevant basic phenomena. The data sets from HRP are very large. Parameters are recorded every 15 minutes. This frequency is much too high to be handled by many computer codes, therefore a condensation is needed. Experience on condensing these data sets has been acquired during the FUMEX exercise organised by the IAEA. This exercise proved that the procedure established is adequate. In addition the condensation is carried out in a way that it practically excludes loss of useful data.

It was recognised, that it is not wise to rely on one source for experimental data only. Independent measurements add to the confidence one can attribute to the results and allow refinements. It was therefore considered important to encourage release of other data to be included in such a data base. Members provided several examples;

- Three fission gas release experiments from Risoe (two experiments are open, the third is in process of general release)
- The RAMP experiments at Studsvik (some of the data is already in the open literature)
- Some experiments carried out at Battelle NW on high burnup fuel might become available

- Indications were given that some data from Canadian experiments might be released
- Data from Nuclear Electric could be useful for mechanistic approaches
- A few experiments, property of Framatome, could be released in the future
- Experiments from CIS on ZrNb alloys, hollow pellets, wall closures would be very valuable

It was stressed that experiments contain uncertainties, for example power histories, therefore results from experiments do not necessarily provide the ultimate truth. There is a need for a filtering process for the data, including correct normalisation.

It was agreed that the data base should be general.

Ideas for indexing the data sets and on the formats were presented by J.A. Turnbull. A matrix structured into issues and coverage was suggested to give a general overview of the data. The coverage could be: HRP, PWR, SWR, WWR, CANDU, AGR, Other; the issues: material properties, thermal performance, fission gas release, dimensional changes, integral effects, high burnup, other.

Each data set should be characterized further in a specific report in computer readable form containing: . objective of the experiment - special features . design of experiment - assembly construction . material properties . dimensions . instrumentation . review of irradiation history and in-pile data . review of post irradiation examinations if any The computer processable part would consist of the . irradiation history . in-pile data

The final choice of structure must take into account portability to a large number of different computer platforms. To achieve this, the format must be kept simple and portable procedures to edit and extract data needed for the modelling should be provided.

A pilot study to better assess the amount of work required to complete the task should be carried out. It was suggested that for the purpose an expert consultant is hired.

V. Time Schedule for Finishing the Report

The more precise schedule is provided in Annex 5. In summary, it was agreed that the final draft should be ready by 15 December 1994. It will be presented to the Bureau of the NSC on 16 December. Members of the group will have time to approve it by the end of December 1994. It will be printed and distributed in the course of January/March 1995.

The same schedule applies to the review paper on experiments prepared by J.A. Turnbull.

With this the objectives of the Task Force have been met within the one year period assigned to it by NSC.

VI. Any Other Business

No need was felt by the group to meet again based on the mandate and the objectives set out by NSC. If the NSC approves the setting up of a data base of experiments, the group could assemble again to monitor progress, to promote release of experimental data needed to render the data base comprehensive to cover special needs emerging in fuel behaviour modelling, to suggest model validation exercises and organise topical meetings on specific issues of high priority. This decision should be made by the NSC and a revised mandate should then be provided.

VII. Summary Conclusions

The Task Force concluded that the original objectives set out were met and the programme of work completed. In addition, one specific action has also been initiated and completed:

- a) The important scientific issues in fuel behaviour in normal operating conditions have been identified and those with highest priority singled out in the report, thus providing NSC advice on what specific research could benefit most from international cooperation. Specific actions were also identified.
- b) The final draft of the report on scientific issues in fuel behaviour is ready and will be published at the beginning of 1995.
- c) Upon approval of the NSC, a review of fuel behaviour experiments was prepared and will be published at the same time as the report.
- d) The recommendations include the setting up of a data base of experimental data of which a first set of 21 experiments should form the basis. In order to better estimate the effort required for this, a pilot study is suggested covering the format of the data base, the compilation and coding of the data to be included. A report on this experience would be provided to the next NSC meeting so that a final decision on the proposal can be taken.
- e) It was recommended that such a data base should be operated, maintained and distributed by the NEA Data Bank.

ANNEX 1

O E C D

Nuclear Energy Agency Nuclear Science Committee (NEA NSC)

Second Meeting of the
Task Force on Scientific Issues in Fuel Behaviour

7 November 1994
Institutt for Energiteknikk, Halden, Norway

AGENDA

1. Welcome
2. Adoption of Agenda
3. Report to NSC
 - Overall Structure
 - Chapter by chapter discussion
 - Proposed recommendations
 - Approval of report
4. Special recommendations and initiatives
 - Status of compilation and review of experimental data base
 - Others
5. Time schedule (for finishing the report)
6. Any other business

ANNEX 2List of ParticipantsNSC Task Force on Scientific Issues in Fuel Behaviour

Halden, 7th November 1994

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* Apologies for not being able to attend the meeting were received

ANNEX 3New Structure of the Report on
Scientific Issues in Fuel Behaviour**Executive Summary**

1. Introduction

- 1.1 Background
- 1.2 Scope, Objectives and Work Programme
- 1.3 Selection of Issues

2. Identification of Important Issues in Fuel Behaviour

- 2.1 Thermal Analysis
- 2.2 Fission Gas Release
- 2.3 Fission Gas Swelling
- 2.4 Stress Corrosion Cracking
- 2.5 Constitutive Equations
- 2.6 Water Chemistry
- 2.7 Hydrogen Measurement Techniques (in cladding)
- 2.8 Failed Fuel Behaviour
- 2.9 Spent Fuel - Long term Behaviour
- 2.10 Quality Assurance Process for Experimental Data Analyses

3. Ongoing Activities

- 3.1 National Activities
- 3.2 International Activities

4. Priorities of Future Work

- 4.1 Coverage of the Selected Topics by International Projects
- 4.2 Identification of Areas of High Priority and Means of Co-operation and Co-ordination

5. Recommendations and Conclusions

- 5.1 Issues of High Priority
- 5.2 Means of Co-operation and Co-ordination

- Appendix A. Selected Issues and their Authors
- Appendix B. High Burnup Fuel in Transient Conditions
- Appendix C. Sequence of Actions/Tasks Related to In-pile Experiments
- Appendix D. Glossary of Abbreviations Used

ANNEX 4Papers distributed at the second meeting on
scientific issues in fuel behaviour

- Agenda
- List of Members and Participants
- Draft Report on Scientific Issues in Fuel Behaviour, November 1994
- J.A. Turnbull:
Summary of Data Available for Code Development and Validation from the
OECD Halden Reactor Project, Norway
- K. Bakker:
The Thermal Conductivity of High-Burnup UO₂ Fuel
ECN NC-021-93
- K. Bakker, H. Kwast, E.H.P. Cordfunke:
The Contribution of Thermal radiation to the Thermal Conductivity of
Porous MO₂. ECN-FX--94-073
- M. Szuta:
Mechanisms of Fission Gas Release from UO₂ (Draft)
- Excerpts from the summary record of the 13th meeting of the CSNI/PWGS
(Coolant System Behaviour) on transient behaviour of high burnup fuel.

ANNEX 5

List of Actions/Schedule for finalising the report

<u>Activity</u>	<u>Responsibility</u>	<u>Deadline</u>
* 1. Write executive summary of the report	Chairman Secretariat	9.XII.94
* 2. Send/authorize pictures for cover page	Lemaignan	9.XII.94
* 3. Restructure the report according to the new outline	Secretariat	1.XII.94
* 4. Integrate transient behaviour into Appendix B	Kelpe	9.XII.94
* 5. Chapter 1: add paragraph, re-arrange order of issues	Secretariat	1.XII.94
* 6. Contact countries not represented in the group and request verification of activities in Chapter 2.	Secretariat	15.XI.94
* 7. Verify list of activities in the countries	Members	9.XII.94
* 8. Review chapter 3 - provide corrections	Members	9.XII.94
* 9. Review section on thermal analysis in the light of comments in III.2	Lassmann	9.XII.94
* 10. Add introductory part to FGR section	Lemaignan	9.XII.94
* 11. Add introductory part to fission gas swelling section	Turnbull	9.XII.94
* 12. Provide to Lassmann text to be integrated into constitutive equation section on zirconium alloys	Valli	1.XII.94
* 13. Revise section on constitutive equations and include view on 1.5 versus 3D approach	Lassmann	9.XII.94
* 14. Add introductory part to the water chemistry section	Chartoin	9.XII.94
* 15. Revise hydrogen measurement techniques section	Kwast	9.XII.94
* 16. Add introduction and revise text of spent fuel section	Furuta Secretariat	9.XII.94

* 17. Write section on software validation for QA section, send to Vitanza	Turnbull	1.XII.94
* 18. Render QA section more homogeneous prune excessive details	Vitanza Chantoin	9.XII.94
* 19. Verify activities of IAEA - amend if if necessary	Chantoin	9.XII.94
* 20. Add text for fission gas release	Turnbull	9.XII.94
* 21. Revise chapter 4 - comment	Members	9.XII.94
* 22. Revise chapter 5 - comment	Members	9.XII.94
* 23. Prepare final draft	Secretariat	15.XII.94
* 24. Provide comments on review of experiments to Turnbull	Members	1.XII.94
* 25. Prepare final draft of review of experiments	Turnbull	9.XII.94
26. presentation of final drafts to NSC	Bureau Chairman	16.XII.94
27. approval of final reports	Members	31.XII.94
28. final corrections if any	Secretariat	mid I.95
29. printing	Secretariat	I/II.95
30. distribution	Secretariat	III.95

The reports, together with the results of the pilot study concerning the data base if approved, will be presented to the full NSC on 31.V.95 by the chairman.

Members are kindly asked to promote release of experimental data to be integrated in the data base and to report possibilities and contacts to the secretariat possibly by 15.V.95

- * A draft version of the summary record had been distributed to Members and several actions have already been completed since. These actions are included here to give the full picture of the decisions taken and work carried out.