ORGANISATION FOR ECONOMIC
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NUCLEAR ENERGY AGENCY

STEERING COMMITTEE
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NUCLEAR SCIENCE COMMITTEE

MEETING OF THE
TASK FORCE ON SCIENTIFIC ISSUES IN FUEL BEHAVIOUR

8th December 1993
Château de la Muette, Paris

NUCLEAR SCIENCE COMMITTEE

Task Force on Scientific Issues in Fuel Behaviour

Summary of the Meeting
8th December 1993

I. Welcome

The chairman (K. Bendiksen) welcomed the participants to the meeting. He provided background information on the setting up of the task force by the NEA Nuclear Science Committee:

- At its 3rd meeting the NSC proposed to investigate needs for improved international coordination in scientific issues in fuel behaviour
- At its fourth meeting in June an in depth discussion was held and the secretariat has provided an overview of the international programme in this field (IAEA, CEC, IFE/Halden R.P., EPRI, bilateral programmes)
- Fuel behaviour topics cover an extensive field of activities as about 200-300 papers are published on the subject every year
- NSC concluded that much of the ongoing research was of a more empirical nature and that there was a need for a better understanding of the underlying basic phenomena
- Consequently NSC has decided to set up a task force on scientific issues of fuel behaviour which should work in consultation with CSNI - IFE/Halden Reactor Project and other international programmes
- The mandate of the the task force is wide and includes many issues to be addressed.

The secretariat welcomed the participants on behalf of NEA. Ph. Savelli Deputy Director, sent regrets not to have been able to personally welcome participants and expressed the wish that the meeting be constructive and productive and that recommendations be issued on areas of scientific work in fuel behaviour which should receive particular attention.

II. Introduction of Participants

Participants introduced themselves and described the responsibilities they have and the projects they carry out in their organisation. The list of participants is enclosed as annex 1. T. Furuta (Japan), F. Iglesias (Canada) and J.A. Turnbull (UK) apologized for not being able to attend, but provided written input to the meeting. The NSC members for Switzerland expressed their willingness to contribute to the work but informed the secretariat that their country would not be represented at this meeting.

III. Scope and Objectives of the Task Force

The proposed Scope and Objectives were discussed next. The chairman pointed out that from the start, all duplication of activities between agencies will be avoided; this is in fact a clear request from NSC. The representative from the IAEA (P. Chantoin) pointed out that it is important to identify the activities each agency is carrying out as well as possible overlap; it should be avoided that different agencies compete for the same scarce resources of manpower and budget in the countries. The chairman clarified that the main objective of the task force was to advise NSC and not to start projects. The proposed work programme of the task force aims at producing a report in which important scientific issues in fuel behaviour are identified, their priority determined and recommendations to NSC issued. Concentration of work on issues with high priority should lead to an improved understanding of basic scientific phenomena underlying fuel behaviour. This report will be discussed by NSC who will then take the decisions they deem appropriate. NSC does not have a budget but can influence programme evolution in member countries.

Concerning the scope participants agreed to drop the term advanced fuel as it is normally used for more commercial aspects, also futuristic approaches were not considered as a topic of priority, as they would require special funding mechanisms for experiments. The work should concentrate on phenomena rather than on specific fuels. The scope will cover phenomena underlying fuel behaviour under normal operating conditions including transients which are not leading to accident conditions. It was pointed out however, that it is sometimes difficult to draw precise borderlines at the level of basic scientific phenomena.

An agreement on the scope and objectives was found and is provided as an annex 2.

IV. Short Presentation of Activities by Participants

Participants presented the activities carried out in their countries and organisations. These are summarized here only briefly. More details can be found in the papers distributed at the meeting and which are listed as annex 3.

The secretariat described briefly some of the NSC projects that might be of interest to the group; among these, burnup credit criticality, radiation heating and damage, plutonium recycling in fast and thermal reactors, LWR core transients, burning and transmutation of actinides and fission products in reactors and chemical thermodynamics were singled out.

The representative from the IAEA described the rather comprehensive and long standing activity in this field carried out in his organisation which includes technical committee meetings, coordinated research programmes and advisory group meetings. More than 20 countries participate in it together with international organisations. The coordinated research project FUMEX (fuel modelling) has attracted a large participation.

K. Lassmann described his major concerns in modelling which include local effects in thermal conductivity, properties of the rim zone, gap conductance at high burnup. He insisted on the need for a data base with well categorized experimental data to improve the understanding of basic phenomena. Another

concern he expressed is the need to help teams in Eastern Europe working in this field, to ensure that they are not dismantled and that the know how is not lost.

C. Vitanza presented the ongoing and future activities of the IFE/Halden Reactor Project. Future work includes high burnup fuel properties, hydriding of cladding, cladding creep, cladding oxide conductivity, small dryouts, crack growth rate versus stress intensity, crack initiation in different alloys, stress corrosion cracking, in-core water chemistry, crud deposition and sensor developments.

J.F. Marin described the main objectives of the French programme in fuel behaviour research: fission gas release and clad coolant interaction with burnup increase, transient behaviour of pellet clad interaction, fuel with recycled plutonium matching the performance of uranium-oxide fuel, fission product retention for different classes of incidents and accidents. He presented the main tools and facilities available in France as well as the role research and development play in interacting with vendors and utilities to produce modelling software.

G. Valli pointed out that although in Italy the activity in this field has been reduced, the modelling capability is maintained for evaluating different fuel cycles, for use in the cooperation with Russia on RMBK reactors and for studying options in actinides transmutation. Their code system will be extended to cover high burnup.

S. Kelppe presented the fuel behaviour studies that are under way in Finland. He introduced work carried out both at VTT and the utilities and their involvement in international projects. The major topics under investigation at VTT are: cladding material, fuel performance code validation, steady state code validation, transients and accident condition modelling. The utilities are concerned with poolside examinations and test reactor irradiations and examinations (VVER fuel).

H. Kwast presented the activity in fuel behaviour carried out at ECN Petten. Their major activity concerns modelling and experimental work on the thermal conductivity effect at high burnup. Thermal conductivity measurements on irradiated fuel are being envisaged by using a laser flash method.

T. Furuta, F. Iglesias and J.A. Turnbull have provided a written contribution describing the activities in Japan, Canada and UK. Their papers are listed in annex 3.

V. Identification of Important Scientific Issues in Modelling Fuel Behaviour

Experimental Data Sets

The need for experimental data sets was first discussed. Modellers do not need so much a data base for programs, but rather a data base containing well characterized irradiation experiments, such as those carried out at IFE/Halden R.P.

Detailed local measurements are available now including post irradiation examination at high burnup, electron microanalyses which are particularly useful to gain scientific insight into fuel behaviour. If data is well characterized and in some standard form and coming from different sources, it should be possible to understand why different fuels behave differently; existing experiments could be squeezed out a little bit more and additional lessons could be learned. Most basic phenomena are interrelated and the material science aspects need to be developed for their understanding. Models need to include all aspects necessary for the understanding of basic mechanisms; at this level, normal and abnormal conditions cannot be distinguished.

It should be investigated, which data sets or subsets can be made available from completed experiments and under which conditions. The IFE/Halden Reactor Project declassifies, with some exceptions, data that has been produced five years earlier. Their data base could form a basis that could be enlarged to include experiments from other projects. The member from the IFE/Halden Reactor Project (C. Vitanza) confirmed that this is feasible in principle, but the question of manpower needs to be addressed also. The quality of these data sets needs to be assessed as well as the limitation in range of the data parameters.

Identification of Subjects

The term fuel behaviour covers very different domains and the group felt that first of all is should be clarified, which domains will be covered by the task force. The need was expressed also that those parts already covered by ongoing programmes should be identified.

In all 13 subjects were identified as being of high importance so that they should be included in the report. These are:

1. Thermal Conductivity

   There was a general consensus that this subject should be assigned high priority as far as local effects are concerned; in particular the thermal conductivity of the rim, of Zircaloy oxide, of the surface area of fuel and inner cladding and the influence of different shapes of the pores. For the conductivity of Zircaloy oxide the mechanism of growth, the nature of the oxide limit need to be addressed. (Section coordinator and editor: K. Lassmann)

2. Spent Fuel

   The long term degradation in dry storage should be addressed, in particular the crack corrosion over thousand years, the effect of in-pile history, oxidation and creep behaviour. (Suggested section coordinator and editor: T. Furuta - to be confirmed) (A study on this subject is being completed in Japan)

3. Fuel Failure Propagation

Better understanding of the secondary fuel failure is required in particular for higher burnup and the effect of water ingress interaction with the fuel. (Suggested section coordinator and editor: C. Vitanza)

4. Water Chemistry

Effect on fuel from hydrogen and zinc etc, (Suggested section coordinator and editor: P. Chantoin)

5. Hydrogen Measurement Techniques

Non destructive analysis for detecting hydrogen in the cladding needs further attention. This is an important subject for high burnup fuel surveillance and for long term fuel storage. (Suggested section coordinator and editor: H. Kwast)

6. Fission Gas Release

This is an old problem which is far from being mastered and understood today. Progress has been reported for release at low temperatures. Models are based on material dislocation and different stress fields. The mechanism of sputtering in ceramics, correlated with athermal release of fission gases needs further investigation. (Suggested section coordinator and editor: J.F. Marin)

7. Swelling

The modelling of fission gas swelling is difficult both from the physics and mathematics point of view. In this report the subject should be restricted to thermal fission gas release and to transients. (Suggested section coordinator and editor: J.A. Turnbull - to be confirmed - NE has devoted considerable attention to this topic)

8. Effect determination of stoichiometry

The correlation of fuel stoichiometry to thermal conductivity in irradiated fuel is of particular importance for high burnup. (Suggested section coordinator and editor: K. Lassmann)

9. Stress Corrosion Cracking - Zircaloy

Predictive modelling in this field needs further development. (Suggested section coordinator and editor: F. Iglesias - to be condirmed - This subject is investigated in particular in Canada)

10. Constitutive Equations

Constitutive equations, both for clad material and fuel should be considered, though not in detail. The advantage is that they are independent of model parameters and are capable of describing the different components in the deformation; volume changes receive a more

general mechanical treatment. This is in particular of relevance for optimizing fuel cycles at extended burnup. (Suggested section coordinator and editor: K. Lassmann)

11. Safety: High Burnup Fuel in Transient Conditions

Recent experiments with reactivity insertion could not be reproduced with sufficient precision by available models. The transient behaviour of fuel should be reviewed in particular for discharge at high burnup. (Suggested section coordinator and editor: S. Kelppe)

12. Quality Assurance Process for new integral experiments

Experiments carried out in different reactors by different teams are often not comparable. As these experiments are expensive there is a need to set up a QA process for new experiments so that the same procedures are used. This subject is particularly suited for international cooperation. (Suggested section coordinators and editors: P. Chantoin, C. Vitanza)

13. Futuristic Approaches

Several ideas emerged during the discussion: change of UO2 matrix, more inert fuel, standing very long storage, non proliferant fuel cycles, special fuel for burning weapon plutonium, thorium fuel cycle. It was agreed that these futuristic approaches, although of interest are not of high priority, they require in addition a big leap forward in understanding basic fuel behaviour phenomena. It was therefore decided to drop this subject.

A table, listing the subjects and coordinators, is provided as annex 4.

VI. Priorities and Recommendations

The subjects retained are all considered as being important. In the final report an agreed ranking of priorities will be provided.

For each subjects the modelling requirements will be specified. In the different sections of the report it should also be clarified what assumptions modelling codes should make, what developments are possible in the statistical and mechanical models and in what form can the data be used inside the code. Some considerations to the structure of modelling codes should be given.

Computer code comparison exercises were singled out as one of the very valuable activities.

Known bilateral and multilateral programmes, if any, covering these subjects will be clearly identified so that duplication is strictly avoided.

VII. Outline of the Report

The chairman presented a proposal for an outline of the report. This was discussed and approved as shown in annex 5.

The secretariat is in charge, apart from the final editing of the report also of writing with the help of members the introduction, the status of ongoing activities and their possible overlap as well as the draft recommendations and conclusions together with the chairman and members. Chapter 3, identifying important issues will be prepared by members having expressed their willingness to contribute. For each subject a coordinator and editor were identified (some need to be confirmed) as shown in annex 4. The other members are invited to provide their ideas and input. Members should provide also a ranking by decreasing priority for the subjects listed as well as a justification for it. This information will be used to prepare chapter 4.

The proposed schedule for producing the report is shown in annex 6. It is planned to transmit the final report to NSC within about one year. The interim report will be discussed at the 5th NSC meeting in May 1994. This discussion will be used to finalize the recommendations.

VIII. Date and Place of Next Meeting

A follow up meeting will be held if some open questions remain in finalizing the report to be submitted to NSC so that a consensus view can be reached and the report approved. Though independent, it would be held in conjunction with the IFE/Halden Reactor Project (HRP) extended board meeting, scheduled for the week starting 30 November 1994.

ANNEX 1

List of Participants

CANADA

* IGLESIAS, Fernando C.
Nuclear Studies-Safety Dept.
Ontario Hydro
700 University Ave.
TORONTO
Ontario M5G 1X6

Tel. +1 (416) 592 4610
Fax +1 (416) 592 4930

FINLAND

KELPPE, Seppo
VTT ENERGY
Nuclear Energy
P.O.B. 1604
FIN-02044 VTT

Tel. +358 (0) 456 5026
Fax +358 (0) 456 5000

FRANCE

MARIN, Jean-Francois
Dir. Reacteurs Nucleaires
Bat. 524
CE/SACLAY
91191 GIF-SUR-YVETTE CEDEX

Tel. +33 (1) 6908 3461
Fax +33 (1) 6908 7985

ITALY

VALLI, Giulio
ERG-RIN
ENEA CRE Casaccia
301, via Anguillarese
00060 Santa Maria di Galeria

Tel. +39 (6) 3048 3150
Fax +39 (6) 3048 6478

JAPAN

* FURUTA, Teruo
Head of Fuel Reliability Lab.
Dept. of Reactor Safety Res.
Tokai-mura, Naka-gun
Ibaraki-ken, 319-11

Tel. +81 (292) 82 5296
Fax +81 (292) 82 5408

NETHERLANDS

KWAST, H.
Unit Materials
Netherlands Energy Research
Foundation ECN
Postbus 1
NL-1755 ZG PETTEN

Tel. +31 (2246) 4606
Fax +31 (2246) 4480

NORWAY

(CHAIRMAN)

BENDIKSEN, Kjell H.
Assistant Managing Director
Institute for Energy
Technology
P.O. Box 40
N-2007 KJELLER

Tel. +47 (63) 80 62 01
Fax +47 (63) 81 11 68

UNITED KINGDOM

* TURNBULL, J.A.
Nuclear Electric plc
Berkeley Nuclear Laboratories
Fuel & Core Division
Berkeley
Gloucestershire GL 13 9PB

Tel. +44 (453) 812 419
Fax +44 (453) 812 004 OR 529

INTERNATIONAL ORGANIZATIONS :

CHANTOIN, Pierre M.
Nuclear Materials and Fuel
NENF, A2504
IAEA
P. O. Box 100
A-1400 VIENNE

Tel. +43 (1) 2360 2763
Fax +43 (1) 234564

LASSMANN, Klaus
Institute for Transuranium
Elements
JRC Karlsruhe Establishment
Postfach 2340
76125 KARLSRUHE

Tel. +49 (7247) 84297
Fax +49 (7247) 4046

VITANZA, Carlo
OECD Halden Reactor Project
Institutt for Energiteknikk
P.O. Box 173
N-1751 Halden

Tel. +47 (69) 18 3100
Fax +47 (69) 18 1120

SARTORI, Enrico (SECRETARIAT) Tel. +33 (1) 4524 1072
OECD/NEA Data Bank Fax +33 (1) 4524 1110
Le Seine-Saint Germain
12 boulevard des Iles
F-92130 ISSY-LES-MOULINEAUX

* sent apologies for being unable to attend

ANNEX 2

OECD/NEA Nuclear Science Committee (NSC)

Task Force on Scientific Issues of Fuel Behaviour (TFSFB)

SCOPE and OBJECTIVES

Scope

The task force will deal with the status and trends of scientific issues of fuel behaviour.

Objectives

- Identify areas of high priority to Member countries which would benefit from international coordination and cooperation concerning the basic underlying phenomena of fuel behaviour under normal operating conditions.

- Provide advice to NSC on the developments needed (data, models, experiments) to meet the requirements for a better understanding of fuel behaviour and for improved predictive models.

A coordination with ongoing studies by other groups and for which this activity would have an impact will be established; duplication of activities will be strictly avoided.

Work Plan

The work plan to be established is intended to lead to a summary report, meeting the specified objectives within one year. An interim report will be presented at the NSC meeting in May 1994.

The final report should contain recommendations on concrete actions that would lead to a better understanding of the phenomena covered by the scope and objectives.

Approved by the task force on 8 December 1993.

ANNEX 3

Papers distributed at the meeting on

scientific issues in fuel behaviour

- Agenda

- List of Members and Participants

- Proposed Scope and Objectives

- G. Valli:
  Activity on Fuel Behaviour Modelling Carried out in Italy

- F. Iglesias:
  Canadian Activities and Issues in Modelling in Fuel Behaviour
  Under Normal Conditions

- H. Kwast:
  Activities carried out at ECN Petten on fuel behaviour

- S. Kelppe:
  Notes on the fuel behaviour research in Finland and future needs

- J.A. Turnbull:
  Nuclear Electic's fuel performance modelling requirements

- J.F. Marin:
  Basic Research on Nuclear Materials and Modelling
  Main Targets and Cahllenges/ Main Tools and Facilities

- K. Bendiksen:
  The IFE/OECD Halden Reactor Project near term research areas in
  fuel performance ; suggested topics for discussion

- C. Vitanza:
  OECD HRP: Comparison of present and next program period
  Main items related to ongoing contract work at Halden

- P. Chantoin
  Programmes and meetings recommended by the IWGFPT

- T. Furuta:
  Current Status of Research and development of fuel behaviour in Japan

- K. Lassmann, C.O'Carrol, J. van der Laar, C.T. Walker
  The radial distribution of plutonium in high-burnup UO2 fuels

- K. Lassmann
  TRANSURANUS: a fuel rod analysis code ready for use

- T. Saario, V.A. Marichev:
  A New contact electric resistance technique for in-situ measurement of the electric resistance of surface films on metals in electrolytes at high temperatures and pressures

- L. Mattila, T. Vanttola:
  YKAE: Research programme on nuclear power plant system behaviour and operational aspects of safety

ANNEX 4

Summary of Subjects for the Report on Scientific Issues in Fuel Behaviour Under Normal Operating Conditions

1. Thermal Conductivity (Lassmann, Kwast, others ...)

   - Local phenomena
   - Fuel (Rim)
   - Zircaloy Oxide
   - Gap nature and conductivity

2. Spent Fuel (Furuta, others, ...)

   - long term behaviour
     (function ---> history)

3. Fuel Failure Propagation (secondary failure) (Vitanza, others, ...)

   - behaviour
   - mechanism

4. Water Chemistry (Chantoin, others ...)

   - effect on fuel (hydrogen, zinc)

5. Hydrogen Measurement Techniques (in cladding) (Kwast, others, ...)

   - non destructive analysis

6. Fission Gas Release (sputtering) (Marin, Valli, others ...)

7. Swelling (transient) (Turnbull, others ...)
   (restricted to thermal fission gas release)

8. Effect determination of stoichiometry (Lassmann, others, ...)
   (only the part related to thermal conductivity)

9. Stress Corrosion Cracking - Zircaloy (Iglesias, Valli, others, ...)

10. Constitutive Equations (Lassmann, Valli, others, ...) (not in detail)

    - cladding;
    - fuel

11. Safety: High Burnup Fuel in Transient Conditions (Kelppe, others, ...)

12. Quality Assurance Process for new integral experiments (Chantoin, Vitanza, others)

ANNEX 5

Task Force on Scientific Issues in Fuel Behaviour

Report to NSC - Outline

1. Introduction (Secretariat)

2. Status (Secretariat, Members)

   - ongoing activities within member countries
   - current overlap of activities

3. Identification of important issues in fuel behaviour (Members)
   (see annex 4 for topics)
   - scientific issues
   - modelling aspects

4. Priorities for future work (Members)

   - ongoing projects
   - new needs and NSC projects
   - identification of areas and means of cooperation and coordination

5. Relation to other Agencies

6. Recommendations and conclusions (Members and Secretariat)

ANNEX 6

Schedule for preparing the report

on scientific issues in fuel behaviour

Activity	Responsibility	Deadline
1. Draft summary of the discussions of the meeting held on 8 December 1993	NEA Secretariat	end 1993
2. Report to NSC bureau	NEA Secretariat	21.XII.93
3. Prepare draft of chapters provide input to coordinators	Coordinators Members	1.III.94
4. Review status of actions	NEA Secretariat	7.III.94
5. Presentation of task force objectives and programme of work to IWGFPT Vienna	NEA Secretariat	III/IV.94
6. Short draft report for NSC	NEA Secretariat	1.V.94
7. Distribution to members for comments and integration of comments	NEA Secretariat	15.V.94
8. Presentation of preliminary report at NSC meeting	Chairman	26.V.94
9. To finalize the report and sort out last issues	Members NEA Secretariat	15.X.94
10. Final discussion, approval of report meeting in conjunction with HRB Extended Programme Group Meeting	All	beginning December 94
11. Final report issued for NSC bureau	NEA Secretariat	December 94