ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

STEERING COMMITTEE
FOR NUCLEAR ENERGY

RESTRICTED

Paris, drafted: 19-May-1994
OLIS: 20-May-1994
dist.: 24-May-1994

NEA/NSC/DOC(94)16

Englist text only

NUCLEAR SCIENCE COMMITTEE

ACTIVITY REPORT OF THE TASK FORCE ON SCIENTIFIC ISSUES IN FUEL BEHAVIOUR 1993/1994

25/26/27 MAY 1994
CHATEAU DE LA MUETTE, PARIS

014167

Activity Report of the Task Force on Scientific Issues in Fuel Behaviour 1993/1994

25/26/27 MAY 1994
Chateau de la Muette, Paris

The Task Force on Scientific Issues in Fuel Behaviour was set up in the autumn of 1993 as endorsed by the NSC at its fourth meeting, June 8-9, 1993.

I. 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.

These objectives were agreed upon at the first meeting of the Task Force.

II. Task Force Meeting

The first Task Force meeting was held in Paris on 8th December 1993 (see summary record NEA/NSC/DOC(94)7). The background leading to the setting up of the task force was explained by the chairman (K. Bendiksen). The NSC found that much of the ongoing research was of an empirical nature and that there was a need for a better understanding of the underlying basic phenomena. Through consultation with experts and other international programmes topics where improvement is needed should be identified.

Participants presented the activities carried out in their countries and organisations: Canada, Finland, France, Italy, Japan, Netherlands, Norway, UK, EU, IAEA and OECD/NEA.

Participants then identified important scientific issues in modelling fuel behaviour; parts already covered by ongoing programmes were included for completeness.

Twelve subjects were identified as being of high importance, and 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 the different shapes of the pores. For the conductivity of Zircaloy oxide, the mechanism of growth and the nature of the oxide limit need to be addressed. (Section coordinator and editor: K. Lassmann, EC Karlsruhe)

2. Spent Fuel

The long term degradation in dry storage should be addressed, in particular the crack corrosion over a period of a thousand years, the effect of in-pile history, oxidation and creep behaviour. (Section coordinator and editor: T. Furuta, PNC)

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. (Section coordinator and editor: C. Vitanza, IFE/HRP)

4. Water Chemistry

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

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. (Section coordinator and editor: H. Kwast, ECN)

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 a thermal release of fission gases needs further investigation. (Section coordinator and editor: J.F. Marin, CEA)

7. Swelling

The modelling of fission gas swelling is difficult both from the physics and mathematics points of view. In this report the subject should be restricted to thermal fission gas release and to transients. (Section coordinator and editor: J.A. Turnbull, NE)

8. Effect determination of stoichiometry

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

9. Stress Corrosion Cracking - Zircaloy

Predictive modelling in this field needs further development. (Section coordinator and editor: F. Iglesias, Ontario Hydro)

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. (Section coordinator and editor: K. Lassmann, EC Karlsruhe)

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. (Section coordinator and editor: S. Kelppe, VTT)

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. (Section coordinators and editors: P. Chantoin, C. Vitanza)

In addition, futuristic approaches were discussed; although of interest, it was agreed that they 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.

III. Programme of Work

A work plan has been established with the intention of producing a summary report, meeting the specified objectives within one year. This report should contain recommendations on concrete actions that would lead to a better understanding of the phenomena covered by the scope and objectives of the task force.

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

For each subject the modelling requirements will be specified and clarified. This concerns modelling assumptions, possible developments in the statistical and mechanical models and in what form data may be used inside the codes.

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

The outline of the report was agreed, and covers the following chapters:

- general introduction;
- the status of ongoing activities within Member countries and other organisations, current overlap of activities;
- scientific issues and modelling aspects of the 12 issues identified as of particular importance in fuel behaviour;
- priorities for future work concerning new needs;
- identification of areas and means of cooperation and coordination, relation to other agencies;
- recommendations and conclusions.

IV. Further Actions and Preliminary Proposals

1. Completion of the report

Good progress has been achieved since the meeting and the work plan runs on schedule. Most chapters exist in draft form and will undergo further iteration. The report should be finalized in the course of September 1994 and distributed as a final draft to the task group members.

2. Final meeting

A follow up meeting will be held to discuss remaining open questions, to reach a consensus view and to approve the report. Actions for the future will be discussed at this time. Tentatively it is scheduled in conjunction with the IFE/Halden Reactor Project (HRP) extended programme group meeting, 30 October - 4 November 1994.

3. Proposed Activities

a) The need for consistent experimental data sets was recognised by the Task Force. After 30 years of testing and development of fuel rods a large body of data and experience exists, e.g. from the IFE Halden Reactor Project. Relevant major results of irradiation experiments are not usually published, however, due to the proprietary nature of these data. In many cases details of the design and the irradiation history are restricted or even missing. Consequently, there are not many experimental results available in the public domain that can be directly used for the validation of fuel rod computer codes.

Modellers do need a data base in some standard format, however, containing well characterized irradiation experiments. Most basic phenomena are interrelated and models must cover all relevant effects, including material science aspects, necessary for the understanding of basic mechanisms.

It is suggested that a consultant be engaged to review and evaluate existing well characterized experiments, covering issues and phenomena of the highest priority. The objective is to identify data sets for which quality criteria are met, and assess consistency, completeness and limitation in range of the data parameters. The best existing format for storage and retrieval of the data should be identified.

The review should concentrate on data sets which can be shared at international level under defined conditions. However, proprietary data sets should also be identified, as it is anticipated that data sets will be more widely released if resources are made available for structuring them into a standard form.

b) The issue of constitutive equations should be addressed; this would be an important step forward in fuel behaviour modelling. Increased availability of well characterized experimental data would improve the knowledge of the parameters of these equations.

c) The understanding of two among the several identified phenomena is considered as being of highest importance for improving fuel behaviour modelling:

- Thermal conductivity:
  although this has been extensively studied, local measurements at different burn-up levels and temperatures are needed in order to better determine the influence of the accumulation of fission products and changes in stoichiometry. All details of the degradation of the local thermal conductivity need better experimental support which must be accomplished by a better theoretical understanding. The thermal conductivity of the rim structure is unknown and needs to be investigated. The surface morphology and composition of LWR fuel and cladding at high burnup should be investigated. The thermal conductivity of zirconium oxide needs further clarification.

- Fission Gas Release:
  no quantitative description of the sputtering (evaporation of fission products along the heated path created by fission products) phenomenon exists today. It is proposed to study the phenomenon by irradiating fuel pellets with heavy ions having masses and energies typical of fission products. The modelling of the phenomenon could in addition be carried out using molecular dynamics calculations. New software developed for advanced chemistry, could be used to compute the chemical state of the xenon atom in the uranium oxide matrix in various interstitial, substitutional or single - or multivacancy sites. Knowledge of the energy of each configuration will allow a better description of the precipitation kinetics of the fission gas in the irradiated fuel.

d) Computer code comparison exercises and benchmark studies would be very valuable. This activity would much benefit from the computer program services of the NEA Data Bank and would ensure that the distributed codes have been validated.