OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

P.O. Box 2008
Oak Ridge, TN 37831-6370
(865) 574-5280
(865) 574-3527
Internet: parkscv@ornl.gov

May 24, 2002

Dr. Carl J. Withee
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop OWFN 13-D-13
Washington, D.C. 20555

Dear Carl:

NRC International Trip Report, Cecil V. Parks, Madrid, Spain, April 16–26, 2002

Enclosed is a copy of the Nuclear Regulatory Commission (NRC) International Trip Report for Cecil V. Parks. The report format is consistent with the guidelines outlined by NRC.

Dr. Parks participated in an International Atomic Energy Agency Technical Committee Meeting on the Requirements, Practices, and Developments in Burnup Credit Applications. The traveler has supported the NRC Office of Nuclear Material Safety and Safeguards in the area of criticality safety and transportation for over 20 years and was the ORNL Project Leader for the research program supporting implementation of burnup credit. This meeting provided a valuable international exchange of information on burnup credit applications and research.

No immediate action is recommended at this time. The report does review some expermental programs that may be of interest to the NRC in regards to burnup credit and high burnup fuel. NRC participation in international meetings of this kind are encouraged due to the opportunities they provide for obtaining technical information and insights into regulatory practice on burnup credit and related issues

Please contact me if you have questions regarding the report.

Sincerely,

Cecil V Parks

Cecil V. Parks
Group Leader, Nuclear Analysis Methods and Applications

CVP:jba

cc: Distribution attached

NRC FOREIGN TRIP REPORT

Subject:
Foreign Trip Report

Dates of Travel and Countries/Organizations Visited:
April 22-25, 2002; Center for Investigation of Energy, Materials and Technology (Ciemat); Madrid, Spain

Author, Title, and Agency Affiliation:
Cecil V. Parks, R&D Group Leader, Oak Ridge National Laboratory (ORNL), Nuclear Analysis Methods and Applications Group, Nuclear Science and Technology Division

Sensitivity:
Not Applicable

Background/Purpose:
To participate in an International Atomic Energy Agency (IAEA) Technical Committee Meeting (TCM) on the Requirements, Practices, and Developments in Burnup Credit Applications. The traveler has supported the Nuclear Regulatory Commission (NRC) Office of Nuclear Material Safety and Safeguards (NMSS) in the area of criticality safety and transportation for over 20 years and was the ORNL Project Leader for the research program supporting implementation of burnup credit. This meeting provided a valuable international exchange of information on burnup credit applications and research.

Abstract: Summary of Pertinent Points/Issues:
The traveler participated in the IAEA TCM on the Requirements, Practices, and Developments in Burnup Credit Applications. The meeting was attended by 53 participants from 18 countries and the IAEA. The traveler found the information obtained from the 41 presentations and numerous personal interchanges and informal meetings to be of significant value relative to technical and regulatory information from the participating countries. The presentations indicate significant international interest in burnup credit and increased efforts to implement burnup credit into nuclear safety analyses. In addition, there seems to be a general consensus towards the technical issues related to burnup credit, but a diversity in the detailed approaches being used to address the issues in safety analyses. Information from particular presentations (e.g., France, Spain) deemed of value to current NRC interests in burnup credit, sources for high burnup spent fuel, and utilization of mixed-oxide fuel are highlighted in the report. Information and recommended actions relative to potential opportunities for NRC to obtain technical data from France and Spain are also highlighted in the report. The future of the IAEA coordination of these activities is unclear due to a change of IAEA staff focused on this area; however, NRC participation in international meetings of this kind are encouraged due to the opportunities they provide for obtaining technical information and insights into regulatory practice on burnup credit and related issues.

Discussion:

BACKGROUND AND INTRODUCTION

Spent fuel transport and dry storage casks have routinely assumed fresh fuel compositions in development of the criticality safety assessment. Taking appropriate credit for the reactivity decrease due to irradiation of the fuel is termed "burnup credit," and there is currently significant international interest in implementing burnup credit in safety assessments. The Waste Management Section of the International Atomic Energy Agency (IAEA) initiated a program in 1997 to support Member State implementation of burnup credit within spent fuel management systems. A series of consultancy meetings have been held to plan and organize an advisory group meeting (AGM) in 1997, a technical committee meeting (TCM) in 2000, and the 2002 TCM discussed in this report.

The traveler was the Oak Ridge National Laboratory (ORNL) leader of an Nuclear Regulatory Commission (NRC) research project seeking to improve understanding of burnup credit issues and facilitate implementation of burnup credit into the licensing process. Also, for over 20 years the traveler has led technical support activities for the NRC Office of Nuclear Material Safety and Safeguards in the areas of criticality safety, radiation protection, and source terms for transport and storage cask licensing activities. The traveler's itinerary for the trip is provided in Appendix A.

OVERVIEW OF TCM

The IAEA TCM on the Requirements, Practices, and Developments in Burnup Credit Applications was attended by 53 participants from 18 countries and the IAEA. The agenda for the meeting is provided as Appendix B, and the list of participants is provided as Appendix C. Notably absent from the meeting was participation from Japan who has been active in the international expert group on burnup credit sponsored by the Organization for Economic Cooperation and Development (OECD) and has been working to apply burnup credit in storage and reprocessing systems. Proceedings of the TCM, including full papers associated with each presentation and summary reports from each work group will be published by the IAEA. The traveler has copies of either the presentation material or the paper for all, but a few (noted by solid circles in Appendix B) of the talks and this material can be provided upon request.

Peter Dyck of IAEA was the lead organizer and Bill Lake of the U.S. Department of Energy (DOE) was the Chairman for the TCM. The meeting was opened by Dyck who gave an overview of the IAEA activities related to burnup credit. Similarly, Michaele B. Raap of the United States represented the OECD Expert Group on Burnup Credit and provided an overview of their activities. Of potential interest to the NRC is the fact that OECD is planning for the Committee on the Safety of Nuclear Installations (CSNI) to perform a review of the burnup credit area. As a part of that activity, the CSNI Secretariat will be sending out a questionnaire to the committee members and other country representatives to comment on 1) facilities where burnup credit is adopted 2) precision and accuracy of burnup data, 3) maximum allowable multiplication factor (k_{eff}), 4) level of burnup credit adopted, 5) issues to resolve, and 6) research programs, etc. Based on this information, it would appear that the NRC representative to the CSNI should be receiving such a questionnaire in the near future.

The traveler felt that, in general, the presentations showed a growing maturity on the part of a broader international community. The Central and Eastern European countries were heavily represented and indicated a growing need to implement burnup credit in storage situations. However, it is obvious that these countries are trying to approach the issue with technical

approaches consistent with that applied in Western Europe and the United States. A major obstacle for these countries is the availability of measured chemical assay data to assist in validation of their depletion/decay codes.

The presentation from the United Kingdom facilities regulator (Simister) indicated that burnup credit is accepted in principle and will be considered on a case-by-case basis. He indicated that applications for burnup credit in reprocessing had been submitted to the regulatory agency for some time, but had been given lower priority largely because modification of the license to allow burnup credit was not as much driven by safety as by economics. More recent arguments that have demonstrated the environmental benefit of reducing the use of neutron absorbers in processes have helped raise the priority, and a license is anticipated this year. British Nuclear Fuels Limited (BNFL) meanwhile is exploring the use of burnup credit for mixed-oxide (MOX) fuel. Jim Gulliford (who has recently moved from AEA Technology to BNFL) gave an excellent review of the technical issues that arise in consideration of burnup credit for MOX fuel as apposed to UO_2 fuel.

Most impressive is the experiment and analysis program that continues to be carried out in France. The French talks indicated continued work to use the results from their extensive experimental program in order to enhance their understanding of the phenomena. Work is ongoing to update their code cross-section libraries to reduce the bias and uncertainty associated with prediction of the fission product inventory and reactivity worth. New experimental programs have been initiated to address validation needs for burnup credit with MOX fuel. The ongoing development and operational testing of measurement systems (using both neutron and photon measurement) to confirm assembly burnup remain an important element of the French approach. A. Lebrun and H. Toubon touched on the extensive experience with measurements and the efforts to tie the measured data to predictions from qualified depletion/decay codes. Toubon noted that measurements are typically within 5% of the recorded burnup for typical fuel burnups, but can be higher than that value for low burnups (<20 GWd/MTU). Lebrun had information on the cost of measurements and estimated the cost to load a cask was about $10,000. However, he conceded that this was assuming a "campaign" where fuel for several casks were measured in one continuous operation.

A significant difference in the application of burnup credit in France from other countries throughout the world is that they have sought a consistent approach regardless of the application area (transport, storage, or reprocessing). Other countries, including the U.S., have adopted different approaches for burnup credit depending on the application area. Since 1998, representatives from industry (EdF, Framatome, and Cogema), the Institut de Radioprotection et de Sûreté Nucléaire (IRSN), and the CEA national laboratory at Cadarache have worked to prepare a new application-independent approach to replace the actinide-only, simple (burnup associated with lowest value of any 50 cm fuel length) approach approved for burnup credit implementation in France for almost two decades. The progress of the various working groups was presented by Caroline Lavarenne of IRSN who is coordinating these activities. Besides the extensive base of experimental data, the French working groups have performed comprehensive studies (mostly unpublished to date) to help understand and demonstrate issues, such as the impact of control rod insertion, impact of MOX assemblies surrounding UO_2 assemblies (increase k_{eff} by 0.015), etc. With all this continual effort, the traveler was struck by the rather modest change in burnup credit that is estimated to be gained (a 1 to 2.6% decrease in k_{eff} at discharge) in comparison to the methodology currently in place in France. It appears the French are taking a deliberate but prudent approach to implementing burnup credit. Lavarenne confirmed the French position that a measurement is needed for loading fuel in a

burnup credit cask. Lavarenne noted to the traveler that the working group hoped to make a formal proposal to the regulatory body for consideration by the end of 2002.

Germany is moving forward with scoping studies (Gmal) on burnup credit in a permanent repository. Time frames out to one million years are being investigated. The presentations from J. C. Neuber of Germany provide independent collaborative support for many of the studies performed in the United States.

The United States was represented by the commercial industry, DOE Yucca Mountain Project (YMP), and the traveler who was supported by the NRC. Tom Doering and Dan Thomas of YMP presented a good overview of the burnup credit approach being used by the YMP and the political picture in the U.S. relative to the future of YMP. Albert Machiels representing the Electric Power Research Institute (EPRI) noted the industry desired a practical burnup credit methodology and sought to set achievable goals that would add value to burnup credit implementation. The goals for a burnup credit methodology as discussed by Machiels were: 1) be practical, 2) support initial enrichments up to 5.0 wt% without a loading offset, 3) allow exposure to burnable absorbers, 4) provide standard axial burnup profiles, 5) allow various cooling times, 6) include the addition of fission products, 7) allow for burnup credit beyond 40 GWd/MTU, 8) allow use of reactor records in place of measurements, 9) provide for BWR applications, 10) provide a standard set of operational parameter values, 11) provide standard validation methodologies, and 12) support standard isotopic depletion codes. Lancaster, a consultant, noted that cask vendors were actively preparing safety analyses seeking burnup credit and indicated fission product credit would be sought and reactor criticals used for validation. Both Lancaster (in his talk) and Machiels (privately) noted the strong opposition by utilities to requiring a measurement for burnup verification prior to loading. Both risk (perceived unnecessary handling of fuel) and cost were cited as utility concerns. Raap, representing the utility seeking to utilize MOX in reactors, discussed the work being done to investigate the implementation of burnup credit for MOX fuel in storage pools at the McGuire reactor site.

The traveler provided an overview of the NRC research program on burnup credit, and the recommendations that resulted from the work. He also presented work to investigate different approaches to estimating the uncertainty in k_{eff} due to the uncertainty in the nuclide inventory. There was considerable interest from many participants relative to the talks. The representative from Korea (Hwang) noted that his utility routinely used the direct methodology whereby the measured and predicted nuclide inventories are applied separately in the k_{eff} analysis of the system, and a comparison made to obtain a measure of the bias and uncertainty. Machiels and Lancaster both showed interest in the work and the results. It seemed to have been recognized that the NRC research program did address many of the goals set forth by industry in the talk by Machiels.

Beginning late Wednesday afternoon and continuing all day Thursday, the TCM was split into four working groups representing four areas: validation of codes and data, key issues, safety assessments and implementation, and future applications. The participants were asked to select a group, although the traveler had been asked to co-chair the key issues working group and could not select. Each working group was asked to provide a brief report on the status and outstanding issues related to each of these areas. An oral report from each group was presented on Friday, and a written report from each group was prepared for publication.

Prior to attendance at the TCM, participants were asked to complete a matrix indicating the status of burnup credit for various fuel types and application areas. This information was

consolidated at the TCM and the preliminary consolidation report is provided as Appendix D. There were some comments provided on this draft that will likely be addressed in the final version, but it does provide an easy means to compare the use of burnup credit in the various participating countries.

BELGONUCLEAIRE REBUS AND MALIBU PROGRAM

Peter Baeten of Belgium presented a review of the REBUS experimental program being coordinated by Belgonucleaire and performed at SCK/CEN. REBUS is an experimental program seeking to obtain reactivity worth information and assay data for use in burnup credit, and the traveler had represented NRC at the initial meeting of the program in 2000. In private, Baeten approached the traveler to discuss the NRC decision to curtail its involvement in the REBUS program. Baeten indicated NRC had paid 50% of the partner cost for the program and then withdrew. He was basically pointing out that NRC would get no data for the 50% cost, but all the data if they could provide the extra funding. Baeten noted that Japan had joined REBUS and the program had expanded in scope since the NRC withdrawal; thus providing more data than planned for the same cost.

Relative to the MALIBU program, a program seeking to obtain assay data from high burnup spent fuel, Baeten confirmed that there was extensive participation from several countries. J. Gulliford, who has extensive experience in similar programs, separately indicated to the traveler that BNFL was participating and he felt it was a valuable program.

SPANISH CSN HIGH BURNUP PROGRAM

The Spanish regulatory body (CSN) in cooperation with Spanish and Japanese utilities has initiated a program to obtain measured assay data from spent fuel irradiated to an estimated average burnup of 68 GWd/MTU. The program will use two rods from a Westinghouse 17 × 17 assembly. The initial enrichment of the rods is 4.5 wt %. The rods were irradiated for 3 full cycles and then pulled and placed in another assembly for another cycle of irradiation. The rods are from the same fuel selected for the Cabri experimental program. Compositions for forty isotopes, selected for their importance to burnup credit, radiation sources, and decay heat, will be measured. The experimental program began in February 2002 and will finish in November 2002. Documentation of the measured data is planned for January 2003 and analyses will be performed in 2003. The schedule seems aggressive, but timely given the need for such data. The CSN presentation to the TCM is provided as Appendix E.

It was noted from the CSN presentation that the data would initially be held as proprietary because of the utility participation. However, it was indicated that CSN wanted public release of the data and was working with the utilities to get release of the data as soon as possible. However, it was conceded that at least initially the data would be held proprietary. The traveler later discussed the program with Jose Conde of CSN to determine if the data might be made available to the NRC. Conde indicated that the data would not be available to the NRC under their bi-lateral agreement. However, he indicated a keen interest in discussing NRC participation in the program, mainly because he felt it would strengthen his arguments to have the data released publicly. The traveler suggested to Conde that independent measurements of the dissolved samples might be of value to the program and perhaps the NRC would be willing to support such independent measurements either in the United States or elsewhere. The traveler also asked about the reconstitution of the rods for the last irradiation cycle. Conde understood the problem relative to code analysis and validation, but indicated extensive effort had been made to obtain the operational details and design of all the assemblies and noted that their had only been one assembly change.

The traveler thinks this program provides a valuable source of data that may be obtained in addition to the measured high burnup data of the Belgonucleaire MALIBU program or in the place of that data.

DISCUSSIONS ON FRENCH BURNUP CREDIT DATA

The traveler was invited by Bill Lake (DOE) and Albert Machiels (EPRI) to meet with them and the representative from AREVA/COGEMA (H. Toubon) to discuss potential acquisition of the French experimental data on burnup credit for use in U.S. licensing activities. Machiels and Lake had separately approached the traveler to tell him that NRC, NEI, and DOE had held a meeting the week before (April 17) to discuss research needs relative to burnup credit and high burnup spent fuel. Machiels noted he had met with the French last fall and that Toubon was the point person for negotiations to obtain the data. The data of interest involves critical experiments, reactivity worth measurements, and assay measurements performed to support UO_2 burnup credit. All but a very small amount of this data is held proprietary by AREVA/COGEMA who paid for the bulk of the work.

The meeting was held on April 24 and was attended by Toubon, Lake, Machiels, the traveler, and T. Doering. Toubon indicated that AREVA/COGEMA was open to negotiating a means to make the data available. This is a notable change in company policy from several years ago when there was no interest expressed. The traveler could speculate that the change may be related to the ongoing efforts in France to establish an expanded burnup credit approach (see discussions above). Cogema may feel that if the data is more openly available and used by other countries, it may help to establish a better consensus on expanded use of burnup credit.

Toubon opened the meeting by giving a brief overview of the type of data available. EPRI and DOE noted interest in pursuing various options for obtaining the experimental data for use in licensing activities in the United States. The traveler noted that as part of the NRC research program on burnup credit, ORNL had reviewed the type of experiments performed and made recommendations to the NRC on the relative value of the experiments to support validation efforts. In addition, sensitivity/uncertainty techniques were later used to help quantify the relative value of the various experiments to validation of codes and data used for burnup credit. The traveler was asked if he could share these letter reports with DOE (Lake and Doering) and EPRI (Machiels) for their review and consideration in planning future discussions with Toubon. (The traveler has since received the approval of Richard Lee, the NRC Project Manager for the burnup credit research program, to distribute the letter reports as requested). The traveler will keep the NRC informed on any follow-on conversations he has relative to the potential acquisition of this data by the DOE and/or EPRI.

SUMMARY

The TCM provided a valuable opportunity for the traveler to stay abreast of the many activities related to burnup credit implementation in various countries and assist his abilities to provide consultation to the NRC staff. The Spanish high burnup assay program and efforts to acquire the French experimental data are two areas that need to be further considered by the NRC staff relative to their interest and potential involvement. Upon further investigation it may be that the Spanish program provides a more attractive alternative to the MALIBU program. Future participation in such meetings is a valuable means for maintaining international contacts in this active field, learning of technical work that supports or helps advance U.S. implementation, and reviewing the various approaches being considered and/or accepted by regulatory bodies.

Pending Actions/Planned Next Steps for NRC:
There are no open actions, but NRC participation in international meetings of this kind are encouraged due to the opportunities they provide for obtaining technical information and insights into regulatory practice on burnup credit and related issues.

Points for Commission Consideration/Items of Interest:
None.

Attachments:
Attachment A - Itinerary
Attachment B - Agenda
Attachment C - List of Participants
Attachment D - Burnup Credit Efforts by Country
Attachment E - Experimental measurements of the Isotopic Composition of High-Enrichment and High-Burnup PWR Fuel

"On the Margins"
None.

APPENDIX A

Itinerary – Cecil V. Parks (XA 157301)

04/16–17/2002	Travel from Knoxville, Tennessee, to Barcelona, Spain
04/18–19/2002	Vacation
04/20/2002	Travel from Barcelona, Spain, to Madrid, Spain
04/21–25, 2002	Attend Technical Meeting "Requirements, Practice and Developments in Burnup Credit Applications"
04/26/2002	Travel from Madrid, Spain, to Knoxville, Tennessee

APPENDIX B

AGENDA

TECHNICAL COMMITTEE MEETING ON THE REQUIREMENTS, PRACTICES AND DEVELOPMENTS IN BURNUP CREDIT APPLICATIONS

Madrid, 22-26 April 2002

AGENDA

Monday, 22 April 2002

9:15 – 10:00

Opening of the meeting	Dyck
Welcome address	CSN Representative
Organizational remarks	Conde/Dyck
Presentation of participants	all

10:00 – 10:45

1. INTERNATIONAL ACTIVITIES: **Chairman: Mr. Lake**

- IAEA Report — Dyck
- OECD/NEA Report — Ms. Brady-Raap

10:45 – 11:15

Coffee break

11:15 – 13:00

2. TECHNICAL TOPICS: **Chairman: Mr. Lake**

2.1 Experimental validation: isotopic composition and reactivity calculations; high burnup fuel implications; nuclear data quality. Session Chair: Mr. Santamarina

- Roque, France: Experimental Validation of Actinide and FP Inventory from Chemical Assays in French PWR Spent Fuels,
- Santamarina, France: Improvement of the BUC-FP Nuclear Data in the JEFF Library.
- Grimm, Switzerland: LWR-PROTEUS Phase II: Reactivity Effects and Isotopic Composition of High-Burnup Fuel
- Alejano, Conde, Spain: Experimental measurements of isotopic composition in high-enrichment, high burnup fuel.
- Baeten, Belgium: First Experimental Results of the REBUS Programme

13:00 – 14:30

Lunch

14:30 – 15:50

- Gulliford, UK: Burnup Credit Validation Experiments, Lessons Learned
- Machiels, USA: EPRI R&D Perspective on Burnup Credit

2.2 Depletion and Criticality parameters that guarantee a bounding approach. Application dependence of BUC parameter importance.

Session Chair: Ms. Brady-Raap

- Neuber, Germany: Impact of the initial enrichment on the end effect.

15:50 – 16:15

Coffee break

16:15 – 17:30

- Hordosy, Hungary: Studies of The Influence of the Spatial Change of the Fuel Burnup on Criticality in VVER-440 Systems
- Chrapciak, Slovakia: Evaluation of horizontal burnup profile for WWER-440 fuel assembly
- Kromar, Slovenia: Burnup Credit Methodology in the NPP Krško Spent Fuel Pool Reracking Project
- Lopez, Spain: VVER Fuel Rod Isotopics Using Monteburns 1.0. Influence of the Isotopic Evolution on the Criticality of the System and Comparison with the Cb3 Benchmark Data.
- Parks, USA: Research to Support Expanded Utilization of the US Guidance on BUC

Tuesday, 23 April 2002

9:00 – 10:45

- Neuber, Germany: Bounding approach in burnup credit criticality safety analysis.
- Kovbasenko, Ukraine:Comparative Analysis of Multiplicating Properties of VVER-1000 Spent Fuel Depending on Assembly Layout in the Reactor Core and their Operation Conditions.
- Lancaster, USA: Bounding approach for BUC applications

2.3 Safety margin, bias, uncertainty and statistical confidence.
Session Chair: Mr.Parks

- Neuber, Germany: Risk, confidence, tolerance and bias - brief outlines of the basic Concepts.

10:45 – 11:15

Coffee break

11:15 – 13:00

- Parks, USA: Strategies for Application of Isotopic Uncertainties in Burnup Credit

2.4 Risk perspective and perception, building consensus. Session Chair: Mr. Conde

- Lake, USA: Probabilistic Assessment of Dry Transport with Burnup Credit.
- Simister, UK: UK Regulatory Perspective on the Application of Burnup Credit in Plant Criticality Safety Cases.
- Doering, USA: Risk Informed Criticality Process

13:00 – 14:30

Lunch

14:30 – 15:45

2.5 BUC assessment scheme: implementation, fuel and loading verification, review of analysis assumptions against changes in the fuel parameters.
Session Chair: Mr. Neuber

- Aydinian, Armenia: Burn-up Factor in Licensing the Spent Fuel Dry Storage of Armenian NPP
- Manolova, Bulgaria: Criticality Calculations of Various Spent Fuel Casks Implementing Burnup Credit
- Zhao, China: Research and Application of Burnup Credit Technology in China
- Markova, Czech Rep.: Burnup Credit Implementation in VVER-440 Dual Purpose Cask

15:45 – 16:15

Coffee break

16:15 – 17:30

- Miasnikov, Czech Rep.: Computer Codes Qualification in the Czech Republic
- Lavarenne, France: A method to take burnup into account in criticality studies considering an axial profile of burnup plus some fission products
- Neuber, Germany: Cycle length, initial enrichment, fuel design and the use of burnup credit methods in Germany
- Vaclav, Slovak Rep.: Utilisation of BUC in the Slovak Republic

Wednesday, 24 April 2002

9:00 – 10:45

- Hwang, Korea: Criticality Analysis with Burnup Credit for APR1400 in Korea
- Smaizys, Lithuania: Possibility for BUC Implementation in RBMK-1500 Fuel Dual Purpose Storage Casks
- Mennerdahl, Sweden: A simple Nuclear Criticality Safety Concept that can be very difficult to implement.

2.6 BUC application to long term storage and disposal. Session Chair: Mr. Doering

- Thomas, USA: Future Disposal Burnup Credit Process
- Gmal, Germany: Burnup Consideration in Criticality Analyses for Final Disposal of Spent Nuclear Fuel in Germany

10:45 – 11:15

Coffee break

11:15 – 13:00

2.7 BUC for MOX and advanced fuel designs. Session Chair: Mr. Gulliford

- Toubon, France: Burn-up Credit methodology for UO_2 and MOX fuel assemblies in AREVA/COGEMA
- Lebrun, France: Cross-checking of the Operator Data used for Burnup Measurements
- Gulliford, UK: Status of Burnup Credit for MOX in the UK
- Brady-Raap, USA: Potential for Burnup Credit with MOX Fuel in US Reactors
- Roque, France: BUC Calculation Route for PWR-MOX Assemblies and Experimental Validation in Minerve R1-MOX Experiment and SLEMP.I.E.

14:30 – 17:30 and Thursday, 25 April 2002, 9:00 – 17:30

Discussion of topics and guidelines for the Group Discussion (~45 minutes)

3. GROUP DISCUSSIONS (4 simultaneous sessions): Chairman: Mr. Lake

- Validation of codes and methods. (Group chair/co-chair: Gulliford/Santamarina)
- Key issues. (Group chair/co-chair: Brady-Raap/Parks)
- Safety assessment and implementation. (Group chair/co-chair: Conde/Neuber)
- Future applications. (Group chair/co-chair: Doering/Toubon)

Friday, 26 April 2002
9:00 – 11:30

4. SUMMARIES OF GROUP DISCUSSIONS Chairman: Mr. Lake

Report of Group Chairs
Panel discussion

11:30 – 12:00
Closing of the Meeting Lake, Conde, Dyck
12:00
Farewell cocktail offered by CSN/CIEMAT

APPENDIX C

List of Participants

Participant	Organization	Country
Mr. Peter Dyck	IAEA	Austria
Mr. Ruben Aydinyan	Armenia Nuclear Regulatory Authority	Armenia
Mr. Peter Baeten	SCK-CEN	Belgium
Mr. Benoit Lance	Belgonucleaire	Belgium
Mr. Philippe Maes	Tractebel	Belgium
Mr. Thierry Maldague	Federal Agency for Nuclear Control	Belgium
Ms. Maria Manolova	Institute for Nuclear Research & Nuclear Energy	Bulgaria
Mr. Wenbin Wei	Qinshan Nuclear Power Company	China
Mr. Shouzhi Zhao	China Institute of Atomic Energy	China
Ms. Ludmila Markova	Nuclear Research Institute Rez	Czech Republic
Mr. Alexander Miasnikov	State Office for Nuclear Safety	Czech Republic
Mr. Yves Chanzy	Transcluneaire S.A.	France
Mr. Stephane Evo	Institut de Radioprotection et de Sûreté Nucléaire	France
Mr. Sylvain Janski	EDF - SEPTEN	France
Ms. Caroline Lavarenne	Institut de Radioprotection et de Sûreté Nucléaire	France
Mr. Alain Lebrun	CEA Cadarache	France
Mr. Jérôme Raby	IRSN/DPEA/SEC	France
Ms. Benedicte Roque	CEA Cadarache	France
Mr. Alain Santamarina	CEA Cadarache	France
Mr. Hervé Toubon	AREVA/COGEMA	France

Mr. Bernhard Gmal	Gesellschaft für Anlagen-und Reaktorsicherheit (GRS)mbH	Germany
Mr. H. J. Kühl	WTI Wissenschaftlich-Technische Ingenieurberatung GmbH	Germany
Mr. Jens-Christian Neuber	Framatome-ANP GmbH	Germany
Mr. Ingo Reiche	Bundesamt für Strahlenschutz	Germany
Mr. Wolfgang Tippl	Framatone-ANP GmbH	Germany
Mr. Dittmar Winterhagen	GNB Gesellschaft für Nuklear-Behälter mbH	Germany
Mr. Gabor Hordosy	KFKI Atomic Energy Research Institute	Hungary
Mr. Jenö Zsoldos	Hungarian Atomic Energy Authority	Hungary
Mr. Hae Ryong HWANG	Korea Power Engineering C., Inc	Korea
Mr. Arturas Smaizys	Lithuanian Energy Institute	Lithuania
Mr. Vojtech Adamovsky	Slovenské elektrárne. A.s. Bratislava	Slovakia
Mr. Vladimir Chrapciak	Vuje Trnava a.s.	Slovak Republic
Mr. Juraj Vaclav	Nuclear Regulatory Authority	Slovak Republic
Mr. Kromar Marjan	Jozef Stefan" Institute	Slovenia
Ms. Consuelo Alejano	Consejo de Seguridad Nuclear	Spain
Mr. Jose M. Conde Lopez	Consejo de Seguridad Nuclear	Spain
Mr. José Gago Bádenas	Enresa	Spain
Mr. David López	SEA Ingeniería y Análisis de Blindajes S.L.	Spain
Mr. Johan Rosenblad	Swedish Nuclear Fuel & Waste Management Co	Sweden
Mr. Dennis Mennerdahl	E. Mennerdahl Systems	Sweden

Mr. Peter Grimm	Paul Scherrer Institute PSI	Switzerland
Mr. Yuriy P. Kovbasenko	State Scientific & Technical Centre on Nuclear & Radiation Safety	Ukraine
Mr. Jim Gulliford	British Nuclear Fuels Limited	United Kingdom
Mr. Greg O'Connor	Department for Transport, Local Government and the Regions	United Kingdom
Mr. David Simister	Nuclear Installations Inspectorate	United Kingdom
Ms. Michaele C. Brady Raap	Battelle Pacific Northwest Laboratory	USA
Mr. T. W. Doering	Bechtel SAIC	USA
Mr. Edward K. Fujita	Argonne National Laboratory	USA
Mr. William H. Lake	U. S. Department of Energy	USA
Mr. D. B. Lancaster	Nuclear Consultants	USA
Mr. A. Machiels	EPRI	USA
Mr. Cecil V. Parks	Oak Ridge National Laboratory	USA
Mr. D. A. Thomas	Bechtel SAIC	USA

APPENDIX D

Burnup Credit Efforts by Country

Burnup Credit Efforts By Country

At Reactor (AR) Storage

Country	PWR	BWR	MOX	VVER	RBMK	Reactor Types[1]
Armenia	na	na	na	INT	na	VVER
Belgium	APU-1	na	na	na	na	PWR
Brazil	APU-2	na	na	na	na	PWR
Bulgaria	na	na	na	INT	na	VVER
China	INT	na	na	na	na	PWR
Czech Republic	na	na	na	INT	na	VVER
Finland	na	Gd	na	INT	na	VVER, BWR
France	Nc	na	Nc	na	na	PWR
Germany	APU-2	Gd	APC-2	na	na	PWR, BWR
Hungary	na	na	na	INT	na	VVER
Japan	INT	INT	INT	na	na	PWR, BWR
Korea	APU-2	na	na	na	na	PWR
Lithuania	na	na	na	na	Nc	RBMK
Mexico	na	Gd	na	na	na	BWR
Netherlands	APU-2	na	na	na	na	PWR
Russia	na	na	na	INT	APU-1	VVER, RBMK
Slovakia	na	na	na	UD-2	na	VVER
Slovenia	APU-2	na	na	na	na	PWR
South Africa	APU-2	na	na	na	na	PWR
Spain	APU-2	Gd	na	na	na	PWR, BWR
Sweden	Nc	Gd	na	na	na	BWR
Switzerland	APU-2	Gd	Nc	na	na	PWR, BWR
Ukraine	na	na	na	INT[2]	No	VVER, RBMK
U. K.	RR-2	na	na	na	na	PWR
USA	APU-2	Gd	UD-2	na	na	PWR, BWR

[1]Burnup credit is not currently envisioned for heavy water or gas cooled reactors so they are not listed.
[2]Burnup credit is allowed by the regulatory law but actions to implement have not beyond.

Abbreviations:
APU-1: Approved and implemented burnup credit using actinide content change.
APU-2: Approved and implemented burnup credit using the change in all isotopes.
APC-2: Approved in concept burnup credit using the change in all isotopes.
Gd: Analysis is performed at the maximum reactivity condition (not zero burnup).
INT: Interested including some early analysis.
na: Not applicable.
Nc: Not being considered but potentially applicable.
No: no interest since the reactor is shutdown
UD-2: Preparing documentation for taking credit using the change in all isotopes.

Dry storage

Country	PWR	BWR	MOX	VVER	RBMK	Reactor Types[1]
Armenia	na	na	na	APU-0	na	VVER
Belgium	Nc	na	na	na	na	PWR
Brazil	Nc	na	na	na	na	PWR
Bulgaria	na	na	na	INT	na	VVER
China	INT	na	na	na	na	PWR
Czech Republic	na	na	na	RR-2	na	VVER
Finland	na	nc	na	nc	na	VVER, BWR
France	Nc	na	Nc	na	na	PWR
Germany	APU-1	Gd	INT	na	na	PWR, BWR
Hungary	na	na	na	INT	na	VVER
Japan	Nc	Nc	Nc	na	na	PWR, BWR
Korea	INT	na	na	na	na	PWR
Lithuania	na	na	na	na	INT	RBMK
Mexico	na	Nc	na	na	na	BWR
Netherlands	Nc	na	na	na	na	PWR
Russia	na	na	na	Nc	INT	VVER, RBMK
Slovakia	na	na	na	UD-2	na	VVER
Slovenia	Nc	na	na	na	na	PWR
South Africa	Nc	na	na	na	na	PWR
Spain	INT	INT	na	na	na	PWR, BWR
Sweden	na	na	na	na	na	PWR, BWR
Switzerland	INT	INT	INT	na	na	PWR, BWR
Ukraine	na	na	na	INT	INT[2]	VVER, RBMK
U. K.	na	na	na	na	na	PWR
USA	APU-M	INT	INT	na	na	PWR, BWR

[1]Burnup credit is not currently envisioned for heavy water or gas cooled reactors so they are not listed
[2]Burnup credit is allowed by the regulatory law but actions to implement have not beyond.

Abbreviations:
APU-1: Approved and implemented burnup credit using actinide content change.
APU-M: Approved and implemented burnup credit using all isotopes for loading and unloading in a borated pool as well as moderator exclusion during dry storage.
Gd: Analysis is performed at the maximum reactivity condition (not zero burnup).
INT: Interested including some early analysis.
na: Not applicable
Nc: Not being considered but potentially applicable.
RR-2: Regulatory review for taking credit using the change in all isotopes.
UD-2: Preparing documentation for taking credit for the change in all isotope concentrations.

Transport Casks

Country	PWR	BWR	MOX	VVER	RBMK	Reactor Types
Armenia	na	na	na	APU-0	na	VVER
Belgium	INT	na	na	na	na	PWR
Brazil	Nc	na	na	na	na	PWR
Bulgaria	na	na	na	INT	na	VVER
China	INT	na	na	na	na	PWR
Czech Republic	na	na	na	RR-2	na	VVER
Finland	na	INT	na	INT	na	VVER, BWR
France	APU-1, UD-2	Nc	UD-1,2	Na	na	PWR
Germany	APU-1, UD-2	Gd	INT	na	na	PWR, BWR
Hungary	na	na	na	INT	na	VVER
Japan	INT	INT	INT	na	na	PWR, BWR
Korea	INT	na	na	na	na	PWR
Lithuania	na	na	na	na	INT	RBMK
Mexico	na	Nc	na	na	na	BWR
Netherlands	APU-1	na	na	na	na	PWR
Russia	na	na	na	APU-1	INT	VVER, RBMK
Slovakia	na	na	na	UD-1	na	VVER
Slovenia	Nc	na	na	na	na	PWR
South Africa	Nc	na	na	na	na	PWR
Spain	INT	INT	na	na	na	PWR, BWR
Sweden	Nc	Nc	na	na	na	PWR, BWR
Switzerland	APU-1	INT	INT	na	na	PWR, BWR
Ukraine	na	na	na	INT[2]	INT[2]	VVER, RBMK
U. K.	RR-1	na	na	na	na	PWR
USA	APC-1,UD-1,2	INT	INT	na	na	PWR, BWR

[1]Burnup credit is not currently envisioned for heavy water or gas cooled reactors so they are not listed
[2]Burnup credit is allowed by the regulatory law but actions to implement have not beyond.

Abbreviations:

APU-0: Approved and implemented burnup credit using fissile content change.
APU-1: Approved and implemented burnup credit using the change in actinide isotopes.
APU-2: Approved and implemented burnup credit using the change in all isotopes.
APC-1: Approved in concept burnup credit using the change in actinide isotopes.
Gd: Analysis is performed at the maximum reactivity condition (not zero burnup).
INT: Interested including some early analysis.
na: Not applicable
Nc: Not being considered but potentially applicable.
RR-1: Regulatory review for taking credit using the change in actinide isotopes.
RR-2: Regulatory review for taking credit using the change in all isotopes.
UD-1: Preparing documentation for taking credit for the change in actinide concentrations.
UD-2: Preparing documentation for taking credit using the change in all isotopes.

Reprocessing

France

At La Hague burnup credit is used for liquids in tanks. This burnup credit utilizes actinides and 15 fission products. Also, burnup credit is currently approved for actinides and burnup credit including fission products will be approved shortly.

Japan

Burnup credit is used in the spent fuel pool which is part of the reprocessing facility. Burnup credit is also used for the dissolver.

Russia

Burnup credit is currently used at the reprocessing facility.

UK

Burnup credit for the reduction of Gd content in the dissolver is expected in May 2002. This burnup credit accounts for the change in actinides only.

Disposal

Reprocessing of fuel eliminates burnup credit for disposal. Also, fuel consolidation eliminates the need for consideration for burnup credit while the container is intact. The Czech Republic, Germany, and Korea, have performed some analysis of burnup credit in disposal. The USA and Sweden have actively pursued burnup credit for disposal to cover failed containers, which contain moderated fuel assemblies. The USA has submitted a Topical Report to its regulatory body describing a burnup credit methodology and have received preliminary approval of the concept.

APPENDIX E

Experimental measurements of the Isotopic Composition of High-Enrichment and High-Burnup PWR Fuel

Technical Committee Meeting on the Requirements, Practices and Developments in Burnup Credit Applications
CIEMAT, April 22-26 2002

Experimental measurements of the Isotopic Composition of High-Enrichment and High-Burnup PWR Fuel

C.Alejano, J.M.Conde - Consejo de Seguridad Nuclear
J.A.Gago – ENRESA
M.Quecedo, J.M.Alonso - ENUSA

Introduction

- Overview of High Burnup Fuel Research
- Background
- Project description
  - Isotopes to be measured
  - Works to be performed
    - Experimental works
    - Analytical works
- Conclusions

High Burnup Fuel Research (2)

- Experimental data on the isotopic composition of fuel with high initial enrichment and high burnup is not accessible
  - Needed to validate fuel burnup codes
  - Specially important for burnup credit in criticality safety analysis (storage and transport)

- A co-operative effort has been started:
  - Consejo de Seguridad Nuclear
  - ENRESA (responsible for waste management)
  - ENUSA (fuel vendor)
  - Other participants: ENDESA and KANSAI (utilities), Mitsubishi Heavy Industries

High Burnup Fuel Research (1)

- National activities:
  - Fuel demonstration programs
  - High burnup fuel irradiation program

- Participation in international projects:
  - CABRI program of the NEA/IRSN
  - NRC high burnup fuel program (bi-lateral agreement)
  - ALPS program of JAERI
  - HALDEN Reactor program
  - Robust fuel program (EPRI)
  - NFIR

Background

- Irradiation extension program:
  - Performed at the Vandellós 2 reactor
  - Fuel rods irradiated up to 65-70 Gwd/MtU (5 cycles)
  - Transported to Studsvik's hot cell laboratory for post-irradiation examination (PIE)
- Valuable material for safety research:
  - Fully characterised
  - High enrichment and high burnup
  - Already included in CABRI and ALPS
- Additional measurements of the isotopic composition of fuel pellets from two of these rods will be performed

Project description (1)

- Objectives:
  - To obtain experimental, independent and suitable isotopic composition data of irradiated PWR fuel
  - Data will be used by the participants as a source of validation of its own calculation methodologies (ex. burnup credit implementation)

- Scope:
  - The isotopic composition of six samples will be determined, with burnup values ranging from 55 to 75 Gwd/MtU (samples now being chosen)
  - Isotopic concentrations to be measured have been selected on the basis of the nuclide importance for criticality, shielding and residual heat calculations. 40 isotopes have been selected.

Project description (2)

- Project contents:
  - Experimental work: Measurements by different proposed methods (gamma-scan, chemical..)
  - Analytical works: Evaluation of and code validation

- Rod description:
  - 17x17 FA design
  - 4.5% enrichment
  - Zirlo cladding
  - 68 MWd/kgU average burnup / 74 MWd/kgU local burnup
  - Irradiated under representative conditions (high duty fuel)

- Schedule:
  - Experimental work started in February 2002
  - Measurement results: November 2002
  - Final report of experimental work: January 2003
  - Analytical work: Before summer 2003

Isotopes (1)

Purpose	Isotopes	Measurement method
Reactivity Relevant	U 234, 235, 236, 238	Chem (HPLC-ICP-MS)
	Pu 238, 239, 240, 241, 242	Chem (HPLC-ICP-MS)
	Am 241, 243	Chem (HPLC-ICP-MS)
	Np 237	Chem (HPLC-ICP-MS)
	Cs 133	Chem (HPLC-ICP-MS)
	Sm 147,149, 150, 151, 152	Chem (HPLC-ICP-MS)
	Nd 143, 145	Chem (HPLC-ICP-MS)
	Eu 151, 153	Chem (HPLC-ICP-MS)
	Gd 155	Chem (HPLC-ICP-MS)
Residual Heat	Ba 137m (Cs 137)	Gamma-scan of the rod
	Pr 144 (Ce 144)	Gamma-scan of the rod
	Rh 106	Gamma-scan of the rod
	Cs 134	Gamma-scan of the rod
	Eu-154	Gamma-scan of the rod
	Cm-244	Chem (HPLC-ICP-MS)

Isotopes (2)

Purpose	Isotopes	Measurement method
Shielding Related	Cm-246	Chem (HPLC-ICP-MS)
Gases	Kr-85	FGR gas mass-spectrometry
Volatiles	Cs 134	Gamma-scan of the rod
	Cs 135	Chem (HPLC-ICP-MS)
	Cs 137	Gamma-scan of the rod
	Ru-103	Gamma-scan of the rod
	Ru-106	Gamma-scan of the rod
Burnup Determination	Ce-140	Chem (HPLC-ICP-MS)
	Ce-142	Chem (HPLC-ICP-MS)
	Nd-146	Chem (HPLC-ICP-MS)
	Nd-148	Chem (HPLC-ICP-MS)

Experimental work (1)

- Measurement of isotopic concentrations using different experimental methods at Studsvik's laboratory

- γ-spectrometry:
  - Axial scanning corrected for dead time losses and decay of the different nuclides since the end of the irradiation
  - Steps between 0.2 and 0.5 mm along the whole length of the rod
  - Additional corrections to account for the γ attenuation, escape probability and detector efficiency in order to calculate the radionuclide inventory in Bq/mm

Experimental works (2)

- Chemical analyses:
  - Diametral fuel pellet and cladding slice cut from the rod, weighted and the fuel dissolved in 65% (v/v) HNO_3 at 60°C in the hot cell.
  - An alliquot of the solution is further diluted and used for the chemical analyses out-of-cell: isotopic dilution using an inductively coupled plasma mass spectrometer (ICP-MS)

- Analysis of released fission gas
  - Isotopic composition of the released fission gas is determined by mass spectrometry of samples of gas retrieved from puncturing of the rod plenum

Experimental works (3)

- Burnup determination
  - Local pellet-average burnup is determined from the inventory of the major heavy metal nuclides (U and Pu) and certain fission products (Ce and Nd) measured by chemical analyses.
  - Experimental measurements are compared with calculation results for the relevant enrichment and irradiation conditions, and the burnup is then found from the equivalent nuclide levels.

Analytical works

- ENUSA is responsible for two analytical activities:
  - Evaluation of the experimental results by comparison with calculation results of reactor irradiation performed with the SCALE system: calculation of the expected isotopic composition of each sample and comparison with the measured concentrations, focusing in the Actinides
  - Analysis of the experimental results with the SCALE system: Accurate calculation of the isotopic composition of each of the six samples within the scope of the project with SCALE system
- Other participants will reproduce the final results using different calculation tools

Conclusions

- There is a lack of accessible experimental data on the isotopic composition of irradiated commercial fuel
- Irradiation research programs have provided high-enrichment, high-burnup PWR fuel
  - Well characterised: inspections and PIE data
  - Correct behaviour under normal operating conditions
- A project has been started to use the available nuclear material for fuel safety research in this field
- The project results will be available early in 2003

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