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Current Status of IAEA Activities in Spent Fuel Management

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Abstract. Spent fuel storage is a common issue in all IAEA Member States with nuclear reactors. Whatever strategy is selected for the back-end of the nuclear fuel cycle, the storage of spent fuel will be an increasingly significant consideration. Notwithstanding considerable efforts to increase the efficient use of nuclear fuel and to optimize storage capacity, delays in plans for geological repositories or in implementing reprocessing result in increased spent fuel storage capacity needs in combination with longer storage durations over the foreseeable future. As storage inventories and durations increase, issues associated with long term storage compel more attention...monitoring for potential degradation mechanisms, records retention, maintenance, efficiencies through burnup credit. Since the IAEA contribution to ICNC99 focused exclusively on IAEA burnup credit activities including requirements and methods, this paper provides a broader perspective on IAEA activities in response to the above trends in spent fuel management, while also describing efforts to disseminate information regarding burnup credit applications.

KEYWORDS: spent fuel management, IAEA, burnup credit, long term storage.

1. Introduction

At the end of last year, 441 nuclear reactors were operating in 31 countries worldwide [1], providing just over 16 per cent of the global electricity supply. Over 10,000 metric tons of heavy metal (tHM) are unloaded from these reactors each year, with annual discharges increasing to ~11,500 tHM by 2010. Since less than one third is reprocessed, about 8 000 t HM/year on average will need to be placed into interim storage facilities.

At the beginning of 2003, about 171 000 tHM of spent fuel were in storage facilities, mostly under water but with an increasing amount in dry storage. The total amount of spent fuel cumulatively generated worldwide by the beginning of 2003 was close to 255 000 tHM. Projections indicate that the cumulative amount generated by the year 2020, the time when most of the presently operated nuclear power reactors will approach the end of their licensed operation life time, the total quantity of spent fuel generated will be approximately 445 000 tHM.

As delays are incurred in implementing reprocessing and in plans for geologic repositories, spent fuel storage for extended durations is becoming a progressive reality.

2. Trends in spent fuel management

This trend of more storage capacity for longer durations is expected to continue. The situation is complicated by trends toward higher initial enrichment, higher fuel burnup, as well as other considerations including the use of evolving fuel designs and mixed oxide (MOX) fuel. Given the importance of effective spent fuel management to sustainable utilization of nuclear energy, member States of the International Atomic Energy Agency (IAEA) maintain an active interest in related work, as evidenced in part by participation in IAEA-sponsored meetings.

An international conference on storage of spent fuel from power reactors was held in Vienna in June 2003. The Conference was organized by the IAEA in co-operation with the OECD's Nuclear Energy Agency. One hundred twenty five participants , representing 35 countries and 3 international organizations, attended the Conference. The participants represented utilities, industry, licensing authorities, national management and research organizations and consultants from most countries with nuclear energy programmes (as well as some non-nuclear countries). The Conference provided an opportunity to exchange information on the current status and prospects of spent fuel storage, to discuss the major factors influencing the national policies in this field and to identify the most important directions for national efforts and international co-operation in this area. Conference participants identified the following conclusions [2]:

- At present, there is sufficient spent fuel storage capacity on a worldwide basis. However, nationally or on a specific site basis, the situation is different and may require urgent attention.
- Wet fuel storage is presently a mature technology with considerable experience and plays a major role in spent fuel storage.

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- Under present conditions, dry storage can also be regarded as an established industrial technology.
- The first geological repositories for the final disposal of spent fuel are not expected to be in operation before the year 2010. Many Member States have not yet started specific site investigations. As a consequence, the use of interim storage will be the primary spent fuel management solution for the next decades in many countries.
- Even more spent fuel storage capacity is required if countries defer their decision to open geological repositories.
- The storage duration becomes longer than earlier anticipated, due to the "wait-and-see" policy chosen by many nuclear power countries. The use of fuel with higher initial enrichment and higher burnup results in higher decay heat and longer storage periods.
- With longer storage periods, dry storage becomes more and more important.
- Several papers (e.g., Arndt et al, Neuber, Danker) noted that application of burnup credit offers an effective tool for mitigating growing storage capacity requirements.
- Several papers described the importance of enhanced communication with a broad range of stakeholders, including the public.

3. Recent IAEA activities in spent fuel management

For the last twenty-five years, the IAEA has been proactively involved in spent fuel management activities. The Nuclear Fuel Cycle and Materials Section within the Department of Nuclear Energy organizes various meetings, often focused on producing technical documentation available to all member States on a topic of interest. While a list of technical documents on this topic published since 1998 is attached to this paper, all IAEA technical documents can be accessed free of charge at http://www-pub.iaea.org/MTCD/publications/tecdocs.asp

As a result of the trends noted above, IAEA activities on spent fuel management have enhanced scrutiny of issues associated with long term spent fuel storage [3]. Recent activities have included the following:

3.1. Long-term Storage of Spent Nuclear Fuel

To address the challenges of extending storage in existing and new facilities for much longer durations, several meetings have been held in recent years, with the results published last year [4]. Resulting conclusions included noting that an extension of knowledge on the creep behaviour of future cladding materials is needed for high burnup and MOX fuel. Additionally, a surveillance programme could demonstrate long term cask and fuel behaviour. Further research activities were also identified for the development and confirmation of performance of advanced dry storage systems. While addressing long term storage of spent fuel in dry systems, participants noted that storage must not be regarded as a final disposal option. As storage durations extend, more attention must be directed toward securing and maintaining related prerequisites, including: technical knowledge, records, stable funding, infrastructure.

3.2. Spent Fuel Performance Assessment and Research

Spent fuel storage technology (particularly dry storage) is undergoing evolution, with modified/new fuel and material designs and increasing target burnup levels. Increased burnup infers higher strains and increased cladding hydriding and oxidation. The Co-ordinated Research Project on spent fuel performance assessment and research (SPAR) addressed research needed to justify spent fuel storage for very long periods of time (more than fifty years). Building on the three earlier BEFAST projects (Behaviour of spent fuel and storage components during long-term storage), SPAR efforts began in 1997 with eleven participating countries, and resulted in a technical document published earlier this year [5]. While this report provided an overview of related technical issues, it specifically addressed materials issues in long-term storage facilities. As storage durations extend, obtaining and extrapolating information on materials behaviour/performance is an important ingredient in continued confidence of implementers and regulators. While results to date anticipate safe dry storage for many decades, participants noted that source terms, including radioactive inventory, initial/final enrichment, must be well known.

3.3. Operation and Maintenance of Spent Fuel Storage and Transport Casks and Containers

As storage durations extend, attention to maintenance is crucial. This task draws on the pool of knowledge that has been accumulated from industrial experience in the past several decades on the operation and maintenance of spent fuel casks. A technical meeting on this subject is being held in October 2003.

3.4. Optimization of Cask/Container Loading for Long Term Spent Fuel Storage

Cask designers face evolving challenges including long term storage of higher burnup fuel with correspondingly higher initial enrichments, the use of

mixed oxide (MOX) fuel, and obtaining regulatory approval for the use of burnup credit. Meetings were held in 2002 and 2003 to identify optimisation issues and obtain views of both regulators and implementers, in preparation for a subsequent technical document on this topic. Participants noted that burnup credit is one of a number of significant considerations in this optimization process. In order to pursue the storage-related advantages of burnup credit, it is necessary to have good knowledge of spent nuclear fuel characteristics, from both measurement and calculations. Quality assurance associated with supporting data remains a key prerequisite to burnup credit implementation. In parallel, refinement of methods/technology for the measurement and confirmation of assembly burnup will be a key contributor to future burnup credit applications. Both meetings endorsed the importance of considering burnup credit, with national representatives noting that related costs and benefits must be evaluated in specific national contexts.

3.5. Dry Spent Fuel Storage Technology

An IAEA Technical Meeting/Workshop "Dry Spent Fuel Storage Technology" was held in June 2002 to give guidance to experts from Central and Eastern European Member States operating WWER and RBMK nuclear power plants and to exchange information. Fifty-six experts participated and concluded that the workshop was very helpful in communicating a wide range of related experience.

3.6. Spent Fuel Treatment

Recent meetings held on the subject of emerging technologies for spent fuel treatment will lead to publishing a technical document in the near future.

3.7. Technical and Institutional Aspects of Regional Spent Fuel Storage

Meetings held in 2001 and 2002 determined that technical considerations and economic issues may be less significant than ethical and institutional issues for the development of a multinational project. A technical document is expected to be published in 2004.

3.8. Selection Criteria for AFR Storage Facilities

Based on meetings held over the several years, a technical document is being prepared to provide guidance on selection criteria and methodology for AFR facilities, together with updated information on related developments.

3.9. Economics of Spent Fuel Storage

Economic considerations in spent fuel storage projects grow in importance as spent fuel storage quantities increase. Meetings held in 2002 and 2003 served as key steps toward ongoing development of a technical document on this subject.

3.10. Data Requirements and Maintenance of Records for Spent Fuel Management

Effective management and protection of storage-related data is a key condition for long term spent fuel management. As data storage technologies evolve and as personnel rotate, continuity of knowledge will require continuing attention. Consistent guidelines on information management are required for long-term management of spent fuel. A meeting, held in early July of this year established a basis for a subsequent technical document on records management.

4. Recent IAEA activities in burnup credit applications

4.1. Implementation of Burnup Credit in Spent Fuel Management

Criticality safety analyses for spent fuel systems traditionally assumed that the fuel was fresh, resulting in significant conservatism. Improved methods (calculations and measurements) for developing solid knowledge of spent nuclear fuel characteristics support efforts to take credit for the reactivity reduction associated with fuel burnup, by reducing this conservatism while maintaining appropriate criticality safety margins.

As described at the ICNC1999 conference, the IAEA started its burnup credit (BUC) programme with an advisory meeting in 1997 resulting in a 1998 proceedings [6] exploring worldwide interest in using BUC in spent fuel management systems. Findings noted that economics was a prime motivator for pursing BUC; gathering needed data consumed time and funds; cooperative development and communication would mitigate these needs.

A second major technical meeting was held in Vienna in July 2000 and attended by 35 participants from 17 countries and 2 international organizations. As noted in the proceedings published in 2001 [7], it concluded that use of BUC, and understanding of related technical and regulatory issues, continued to progress. It also reiterated recommendations that BUC information and data be cooperatively developed and shared, including opportunities for international cooperation in organizing training courses on BUC applications.

In October 2001, the Agency contributed to a well-received two-week BUC training course held in the USA involving 25 participants from 12 countries.

The IAEA organized a third major BUC meeting in April 2002 on requirements, practices, and developments in BUC applications. Fifty-four participants from 18 countries participated in 8 sessions held in Madrid, Spain, involving forty reports and discussions in working groups. These groups addressed validation of codes and methods, key issues, safety assessment and implementation, and future applications. This meeting encouraged the Agency to continue its activities on burnup credit including dissemination of related information, given the number of member States having to deal with increased spent fuel quantities and extended durations. A technical document [8] detailing these discussions on the progress and status of BUC applications for spent nuclear fuel will be published in 2003.

During the June 2003 international conference on spent fuel storage, a panel of experts addressed the topic of "technical and regulatory challenges raised by long term storage". During their discussions, they noted that wider adoption of burnup credit could reduce the total number of casks required for storage and transport applications, with attendant reductions in both expense and exposure.

5. Future IAEA activities in spent fuel management

Participants in the June 2003 spent fuel storage conference expressed particular interest in the following areas for possible future Agency initiatives:

- Providing assistance in the evaluation and research of the long term behaviour of fuel and storage components in order to realize the anticipated long storage periods; (e.g. organizing a regional technical co-operation project on storage issues for Eastern European spent fuel);
- Continuing the exchange of information and data on spent fuel storage technologies and public acceptance matters;
- Broadening the scope of future conferences (e.g. to include safety requirements for storage facilities, criticality issues, burnup credit, decay heat calculations, transport of spent fuel, safeguards);
- Collaborating internationally on specific issues such as fuel integrity, application of burnup credit, code validation, cask component lifetime, long term performance monitoring;
- Representatives of Member States with smaller nuclear programmes informally expressed continued interest in regional storage initiatives, as well as topic-specific workshops and training courses.

The current spent fuel programme for the IAEA includes the following efforts over the next few years:

5.1. Spent Fuel Performance and Research

Building on the results of the coordinated research project on SPAR [4], a subsequent coordinated research project (SPAR-II) is planned for 2004 through 2008 and focused on continued data sharing as storage durations lengthen. Specific research objectives are expected to involve surveillance and monitoring programmes for spent fuel storage facilities, fuel materials performance evaluation for wet/dry storage, and collection and exchange of spent fuel storage experience.

5.2. Burnup Credit Applications

A new task is foreseen on "Advances in applications of BUC to reduce the number of transports and increase storage capacity" with plans for a consultants meeting in 2004 in preparation for a major technical meeting in 2005. In addition, a second task is being investigated to prepare a document on BUC applications to WWER fuel, conditioned on the availability of USDOE-funded chemical assay data.

5.3. Classification of Fuel Failures during Spent Fuel Storage

The Agency plans to collect information from consultants and in larger technical meetings with the intent of subsequently publishing a technical resource documenting national approaches and related issues and recommendations.

5.4. Issues around spent fuel treatment (reprocessing, conditioning, transportation)

This activity will focus on aspects of spent fuel management other than spent fuel storage. Meetings will be scheduled to gather information leading to updated technical documentation on this subject.

5.5. Influence of Fuel Design for High Burnup and MOX Fuel and Advanced Reactor Operations on Spent Fuel Storage

This activity will involve meetings focused on trends on in fuel design which are significant to spent fuel management, leading to a technical document on this topic.

5.6. Good Practices to Extend Operation of Interim Spent Fuel Storage Facilities

Motivated by a desire for consistency in spent fuel storage practices, the IAEA plans to prepare an update to previously issued guidance documents on this topic [9]. Current plans call for a technical meeting in early 2005 to develop this revised guidance.

5.7. Other

As noted above, a range of technical documents will be published on the topics including: data requirements and records maintenance, economics of spent fuel storage, operations/maintenance of casks and containers, regional spent fuel storage aspects, optimisation of cask/container loading. Coordination and cooperation will continue both within the IAEA (e.g., with Nuclear Safety in developing standards) and with other organizations (e.g., with the NEA in activities related to burnup credit). The IAEA will continue to seek opportunities using technical cooperation resources to assist member states in spent fuel management activities. The IAEA will also continue plans for periodic large conferences on this topic to foster a wide exchange of current information and to stimulate creative dialogue on emerging trends.

6. Summary

Spent fuel storage has been carried out safely and effectively for decades, and there is high confidence that this will continue to be the case. Yet as storage inventories and durations increase, issues associated with long term storage compel more attention, as witnessed by participation of IAEA member States in the June 2003 international conference on storage of spent fuel from power reactors. Trends toward more storage capacity for longer durations is complicated by trends toward higher initial enrichment, higher fuel burnup, as well as evolving fuel designs. As a result of these trends, IAEA activities on spent fuel management have enhanced scrutiny of issues associated with long term spent fuel storage. Recent activities have examined issues associated with materials aging, performance monitoring, economics, maintenance, data requirements, cask loading, spent fuel treatment, regional facilities, and facility selection criteria. The IAEA also continues to place significant priority on activities associated with implementation of burnup credit, given the potential for increased capacity and resultant reduced costs and operational exposure.

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- IAEA-TECDOC-1012 - Durability of spent nuclear fuels and facility components in wet storage (1998)
- IAEA-TECDOC-1013 - Implementation of burnup credit in spent fuel management systems (1998)
- IAEA-TECDOC-1061 - Remote technology in spent fuel management (1999)
- IAEA-TECDOC-1080 - Procedures and techniques for the management of experimental fuels from research and test reactors (1999)
- IAEA-TECDOC-1081 - Spent fuel storage and transport cask decontamination and modification (1999)
- IAEA-TECDOC-1089 - Storage of spent fuel from power reactors (1999)
- IAEA-TECDOC-1100 - Survey of wet and dry spent fuel storage (1999)
- IAEA-TECDOC-1103 - Status and trends in spent fuel reprocessing (1999)
- IAEA-TECDOC-1192 - Multi-purpose container technologies for spent fuel management (2000)
- IAEA-TECDOC-1241 - Implementation of burnup credit in spent fuel management system (2001)
- IAEA-TECDOC-1293 - Long term storage of spent nuclear fuel – survey and recommendations (2002)
- IAEA-TECDOC-1316 - Effects of radiation and environmental factors on the durability of materials in spent fuel storage and disposal (2002)
- IAEA-TECDOC-1343 - Spent fuel performance assessment and research (2003

TOPIC 1

STANDARDS AND METHODOLOGY FOR CRITICALITY SAFETY

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