EXECUTIVE SUMMARY

1. Introduction

This report documents the proceedings of the International Workshop on "Safety of Long Term Interim Storage Facilities" held in Munich, Germany, at the Hotel Holiday Inn Munich-City Centre on 21 – 23 May 2013. The workshop was organised by the Committee for the Safety on Nuclear Installations (CSNI) of the OECD/Nuclear Energy Agency (NEA) and hosted by the Gesellschaft für Anlagen und Reaktorsicherheit (GRS) mbH.

Ninety registered specialists from operators, industry, national nuclear authorities, technical support organizations and research institutes, representing 14 NEA countries and two international organisations attended the workshop. A total of twenty nine papers were presented and discussed in an open forum.

2. Background

Many radioactive materials within the nuclear fuel cycle present a significant hazard for 50 years or more. Such materials include spent nuclear fuel, high-level waste, legacy waste and other nuclear materials that have no current outlet than storage. These materials are often held in long-term storage as an interim stage within their lifecycle. Lifecycles can include reuse or disposal. Hazards require effective safety to maintain the risk of realising those hazards to as low a level as reasonably possible. Hazards that extend beyond the life of a facility in which they are generated require careful management and understanding of their safety.

Thus, the Working Group on Fuel Cycle Safety (WGFCS) in cooperation with the Working Group on Fuel Safety (WGFS) aimed within the International workshop to advance the understanding within NEA member countries of safety of long term interim storage across the whole of the nuclear fuel cycle by bringing together and discussing the strategies and practices of storing High Level Waste and Spent Nuclear Fuels.

3. Objectives and structure of the workshop

The objective of this workshop was to discuss and review current national activities, plans and regulatory approaches for the safety of long term interim storage facilities dedicated to spent nuclear fuel (SF), high level waste (HLW) and other radioactive materials with prolonged storage regimes. It was also intended to discuss results of experiments and to identify necessary R&D to confirm safety of fuel and cask during the long-term storage. Safety authorities and their Technical Support Organisation (TSO), Fuel Cycle Facilities (FCF) operating organisations and international organisations were invited to share information on their approaches, practices and current developments.

The workshop was organised in an opening session, three technical sessions, and a conclusion session. The technical sessions were focussed on:

- National approaches for long term interim storage facilities;
- Safety requirements, regulatory framework & implementation issues;

- Technical issues & operational experience, needs for R&D.

4. Summary of the technical sessions

Each session consisted of a number of presentations followed by a panel discussion moderated by the session Chairs. A summary of each session and subsequent discussion that ensued are provided below.

Session 1: National approaches for long term interim storage facilities

This session was chaired by Arturo Bevilacqua (IAEA) and Veronique Lhomme (IRSN, France).

Seven papers were presented during this session by representatives of research institutes in USA (EPRI) and in Norway (IFE), governmental authorities for the nuclear industry in Finland (STUK) and Slovak Republic (ÚJD), technical support organizations in Germany (GRS) and France (IRSN) and the public company in charge of waste management in Spain (ENRESA).

The papers discussed the national policy, the regulatory framework and the current situation for storage of SF and HLW in various European countries (Germany, Spain, Finland, Norway and Slovak Republic). The main activities the EPRI is undertaking to establish the technical bases for extended (long-term) storage and the IRSN's definition of the safety principles and objectives for new storage facilities regarding long-term storage are also discussed.

Summary of papers

Mr John Kessler (EPRI, USA)
Extended (long-term) Used Fuel Storage: EPRI Perspective and Collaboration Initiatives

Mr Kessler pointed out the need to technically develop the basis to support the inevitable renewal of storage licenses due to the limited reprocessing and no disposal capacities. It was also emphasized that transport after storage is an important component to be accounted for. The Extended Storage Collaboration Program (ESCP) was launched in 2009, currently brings together nearly 200 members from about 20 countries and comprises 6 Subcommittees so far. The recently established Subcommittee on Ageing Management is looking for participation.

The 1st Phase of ESCP dealt with a gap analysis that identified the highest priority items are the stress corrosion cracking (SCC) of welded stainless steels (SS) canisters and the hydride effects (reorientation and embrittlement) of high burnup fuel cladding. The ongoing 2nd Phase of ESCP deals with modeling on heat transfer models (effects in SCC and temperature peak at drying) and laboratory testing on identification of conditions supporting SS SCC, correlation of marine environments and salt deposition, bolts and seals degradation and adequacy of drying.

Mr Kessler announced that the 3rd Phase of the ESCP, the Full-Scale High-Burnup Extended Storage Confirmatory Demonstration, was started in May 2013 with the US DOE providing up to 80% funding to address one of the major concerns: The reorientation of hydrides during the initial drying process and its relation with the Ductile Brittle Transition Temperature (DBTT) which is a key parameter regarding the transport after dry storage.

Ms Sandra Geupel (GRS, Germany)
Interim Storage of Spent Nuclear Fuel before Final Disposal in Germany – Regulator's View

Ms Geupel presented the policy, the regulatory aspects and the SF and HLW storages in operation in Germany. The German concept is dry storage of SF and HLW in casks emplaced in storage buildings. The

licensing procedure comprises applications for the storage license and for the type B(U) package approval (considering that one of the most important requirement is that a storage cask has to be transportable at any time during storage). The safety requirements for dry casks storages are published in guidelines (last version in 2012) which establish that the confinement of radioactive material is to be ensured by the cask, the fuel matrix and the cladding tubes and present the SF related requirements (assuming that the integrity of the structure of SF assemblies has to be maintained to ensure the main safety functions).

Each interim storage facility for SF and HLW will be submitted, every 10 years, to a periodic safety review (PSR) which guidelines (adopted in November 2010) are currently under a testing period in two selected storage facilities (Gorleben and Lingen) before coming fully into force. Ms Geupel emphasized also on the importance for considering ageing management for dry casks storage during the whole storage period.

Mr Jean-Pierre Carreton (IRSN, France)
French Approach for Long-Term Interim Storage Safety

Mr Carretonintroduced the results of the work program undertaken by IRSN aiming at defining the safety principles and objectives for new storage facilities statement regarding long-term storage (given that the magnitude of the “long-term” can be estimated at a few hundred years compared to a few decades for current storage). According to this long storage lifetime, it should be sought as far as possible a design combining simplicity and robustness, and incorporating sufficient margins to take into account technical or regulatory uncertainties related to the time scale referred. In this framework, provisions for surveillance and maintenance of the facility and the stored objects, and retrieval, at any time, of the stored objects are of primary importance. Hazards of natural and human origins and ageing are also to be considered.

In France, it is estimated that it is not necessary to set a lifetime for a long-term storage facility; extension of operation lifetime is subjected to PSR (every 10 years) where the applicant safety cases have to show that the safety requirements are always met.

Mr Francisco Javier Fernandez Lopez (ENRESA, Spain)
Spent Fuel Long Term Interim Storage: The Spanish Policy

Mr Fernandez Lopez described the responsibilities of the SF management stakeholders and presented the inventories of SF as well as HLW and MLW from reprocessed SF to be stored at the Centralized Interim Storage (CIS) facility to be built in Villar de Cañas, Cuenca, after the site selection was approved in December 2011. Although the deep geological disposal of SF and HLW is the preferred option for the Spanish Nuclear Program, societal acceptance and more studies have still to be developed. In such scenario the current priority is the ATC.

The technology for the CIS was selected by analyzing the currently available wet (pools) and dry (casks, silos, niches and vaults). The vault technology was selected for SF and HLW by reviewing existing facilities in France (Cascad, Marcoule and La Hague), Hungary (Paks), The Netherlands (Habog) and the USA (Fort St. Vrain) and designed by updating a facility proposed in 2003. The main engineering companies to build the CIS have been already selected. A Research Center will support the construction and operation of the CIS and it lately will become an integral part of a technological center expected to be used by different industries and to serve as a seed for technology based companies.

Mr Fernandez mentioned that the CIS is being designed for an operational life of 100 years and the canisters that contain the SF assemblies are not expected to be opened, however, the wells that contain the canisters could be periodically inspected. He also pointed out that the next phase of the project that includes the PSAR and the EIA is ongoing. The ATC solves the SF, HLW and MLW storage for the next 60 years and it is expected to be operational in 2017.

Ms Päivi Maaranen (STUK, Finland)
The Spent Fuel Management in Finland and Modifications of Spent Fuel Storages

Ms Maaranen presented the current SF management organization in which the utilities TVO (Olkiluoto NPP operating two 880 MWe BWRs, one 1600 MWe EPR under construction) and Fortum (Loviisa NPP operating two 496 MWe VVERs) established Posiva as the organization responsible for the encapsulation and disposal of their SF at Olkiluoto. The third utility Fennovoima (Hanhikivi NPP project) has to present the plan for managing its SF in 2016 that could be either to join Posiva or to propose other alternative.

The TVO project to double the wet SF storage capacity at Olkiluoto NPP in order to serve the operating reactors as well as the one under construction was presented. Three additional SF pools are being built as a major plant modification (adjacent to the existing three SF pools) by applying new safety requirements. The facility will have an outside embankment and the pools will be covered by slabs. Details of the construction were given and the occurrence of the inward bulging of the protective element wall and the loss of air tightness within the radiation protection monitoring area were described.

Ms Maaranen explained the modifications to the SF storage facilities due to Fukushima Daiichi including external cooling water connections (planned before Fukushima Daiichi), independence of power supply for water level and temperature monitoring, and on-site transportable fire water supply and improved availability of source water. New regulatory requirements for SF pools as the concept of practically eliminated occurrences (loss of cooling) and the 72 hours self-sufficiency criterion (monitoring of water temperature and level, and water availability) which may be a challenging tasks if applied to old facilities, were presented.

Mr Peter Bennett (IFE, Norway)
Storage of Spent Nuclear Fuel in Norway: Status and Prospects

Mr Bennett presented an overview of the SF (arisen from irradiation of nuclear fuel in 4 research reactors) in Norway. This fuel is currently stored on-site, by the reactor's operators, in either wet (one site) or dry (three sites) storage facilities.

In 2010/2011, several independent committees (including experts and stakeholders), established by the Ministry of Trade and Industry (MTI) of Norway, have advised the Government on, among others, policy issues, storage methods and localisation of a storage facility for the long-term management of the SF. But the current situation is a strong opposition, from "environmental" organizations, to reprocessing of the legacy metallic Uranium fuel and an opposition of local governments in all potential sites where possible location for a long-term interim storage facility has been identified. In addition, the organizational and financial framework for the storage facility has to be defined as soon as possible (on the principle that the polluter pays).

Mr Juraj Vaclav (ÚJD, Slovak Republic)
Spent Fuel Management in the Slovak Republic

Mr Vaclav presented the legal framework developed between 2000 and 2006 comprising binding laws (describing general requirements) and regulations (describing requirement in more detail) as well as non-binding guides issued by the regulatory authority ÚJD. SF to be stored encompasses those from the VVER reactors at Bohunice and Mochovce NNPs. All the SF from the HWGCR reactor A1 (being decommissioned after a partial core melt accident in 1977) has been transported back to the Russian Federation.

The periodical safety review for SF storage facilities is performed every 10 years e.g. the wet-type Interim Spent Fuel Storage Facility (ISFSF) at Bohunice NPP was licensed for the period 2000-2010 and the operator prepared in 2009 the Periodical Nuclear Safety Evaluation Report in which 32 corrective measures were listed and evaluated to have high, medium and low priority. The inclusion of measurements of alpha activity of radionuclides collected on aerosol filters from the ISFSF to the environmental monitoring program is an example of high priority measure. After implementing the first priority measurements the operator submitted in 2010 the application for a new 10 years operational license of the ISFSF which was granted by ÚJD. By the end of 2012 the operator implemented the medium priority measures.

Following the accident at Fukushima Daiichi, ÚJD requested all NPP operators to perform "stress tests" and the Special National Report – not covering the ISFSF at Bohunice – was completed in April 2012. In 2012 the operator of the ISFSF sent to ÚJD the "Program evaluation-review ISFSF response to the Fukushima event type" which according to ÚJD evaluation confirms that all goals were met.

Mr Vaclav also presented the licensing of the C-30 transport container (designed in the former DDR for VVER SF) on a 5-year period basis and the reduction of the minimum cooling time before transport (ranging from 1.8 to 3.6 years), the R&D activities supported by ÚJD including SF BUC methodology, and SF transport and storage in C-30 transport container with T-12 or KZ-48 baskets and the SF monitoring system deployed by the operator in the wet-type ISFSF at Bohunice.

The important points, and recommendations, from the presentations and the open discussion from the floor with all the presenters of the session 1 are the following:

- Because of the constant acquisition of knowledge on the topic (notably by the way of active and planned R&D), we will be better prepared to deal with storage issues regarding high burnup and MOX spent fuels than with UOX fuel.

- It appears of crucial importance to consider the impact of non-technical aspect (e.g. public confidence and political commitment) in the management of radioactive materials including spent fuel (e.g. an extreme case is represented by Norway).

- Two main concepts are implemented for the storage of spent fuel: Wet storage in pools and dry storage in casks (mostly dual-purpose casks, for the storage and transport), vaults and silos. The storage in pools does not seem to have been questioned because of the Fukushima accident; but lessons learned from this accident must be taken into account, especially regarding the operation of the pools.

- Regarding long term storage, the magnitude of the "long term" can be estimated at several decades to a few hundred years compared to a few decades for current "short term" storage. Current experience is limited to about five decades for the storage of spent fuel.

- Most of the countries are about to implement a site for long term storage for minimum 50 years but design basis must be for 100 years. Given that, it is necessary to take into account safety margins and changes in regulations, climate, public confidence and political commitment, etc.

- For such a long period of storage, the importance of surveillance and ageing management as well as the necessity of doing periodic safety reviews (e.g. every ten years in Germany or France) is underlined. It is also important that the recovery of the stored objects at any time during their storage should be taken into account in the design of a long term storage facility.

- There is a number of ongoing research programs addressing the technical gaps related to HBU fuel behaviour during long-term storage and subsequent transportation.

Session 2: Safety requirements, regulatory framework & implementation issues

This session was chaired by Jose Manuel Conde (CSN, Spain) and Jennifer Davis (NRC, USA).

Eleven papers were presented during this session by representatives from international groups (the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA)), representatives of regulatory bodies from the United States (Nuclear Regulatory Commission) and Germany (Bundesamt für Strahlenschutz (BfS)), German Federal Institute for Materials Research and Testing (BAM), operators from the United Kingdom (Sellafield Limited, UK) and France (EDF), vendors (AREVA), and representatives of TSOs in Germany (TÜV and Öko-Institut).

Summary of Papers

The first paper, "IAEA International Working Group on Integrated Transport and Storage Safety Case for Dual Purpose Casks (DPC)," was presented by Yumiko Kumano (IAEA). This paper described development of a guidance document for preparation of a safety case for a dual purpose cask. The guidance document is close to finalization, and considers various aspects for demonstrating safety, including ensuring safety during transportation, assuming the cask cannot be opened after the storage period. The paper pointed out difficulties based on (1) the difference in licensing processes for storage and for transportation, (2) aging of DPC components, (3) technology development, etc. The working group also developed recommendations for changes to be made to existing IAEA documents.

In the second paper, "Adaptation: The Key to Successful Interim Storage is Anticipating Change," Jennifer Davis (NRC, USA) described some potential alternative licensing approaches and design approaches to account for the possibility of any combination of cladding degradation, storage canister degradation, and/or storage overpack degradation. The paper concluded that adaptive designs may have an advantage over more traditional approaches, and although they may be costly to develop, they could be more economical over the long term.

The third paper, "Actual Situation and Further Development of Interim Storage of Spent Nuclear Fuel and HighLevel Active Waste (HLW) from the View of the Competent Authority in the Field of §6 Atomic Law in Germany," was presented by Christian Drobniewski of BfS. This paper described the challenges associated with developing regulations and concepts for extended interim storage in the changing environment. It was noted that the final disposal method chosen (still undetermined) will have a huge impact on what happens before hand – conditioning and interim storage both depend on the final disposal method. In addition, changes in digital storage could impact documentation integrity. Recommendations included the need for personnel with appropriate experience, the need for basing the safety case for final disposal on information gathered during interim storage, and that personnel and logistical issues need to be addressed, which is not trivial given the long time periods of applicability.

Paper number four, "Sustainable Solutions for Nuclear Used Fuels Interim Storage" was presented by Marc Arslan of AREVA. This paper discussed some of the challenges related to extended interim storage of spent nuclear fuel at reactor sites, including high burn-ups and associated constraints, and provided some potential solutions, including canister storage in concrete overpacks, dry storage in vaults, dual purpose casks, and "Universal Canisters generated by recycling". It also showed important features for wet storage especially as regards the retrievability of the SF in the long term , with no thermally activated phenomenon which can affect the integrity of the used fuel .

The fifth paper, "Safety Aspects of Long Term Spent Fuel Dry Storage" was presented by Peter Hinterding of TÜV, Germany, who concluded that dry cask storage has demonstrated safe and reliable operation, although safety assessments for interim storage facilities can be challenging, and must consider site specific conditions. In addition, storage concepts for very long term interim storage of SNF and high level waste must be developed given the delays in finding final repository solutions.

Marion Astoux of EDF, France, presented "Safety Considerations for a Wet Interim Spent Fuel Store at Conceptual Design Stage," for a site in Somerset England. Included in the safety requirements and design approach were considerations for criticality control, heat removal, containment, shielding and retrievability. In addition, the lessons learned from Fukushima were considered as design input.

In the seventh paper, Frank Wille (BAM, Germany) presented a perspective on transportation preparation after interim storage of SNF and HLW. In Germany, all storage casks must also have a transport approval certificate. Challenges identified include the behaviour of aged metal and elastomeric seals, aged packages subjected to regulatory test requirements, and the aging behaviour of SNF assemblies.

Claudio Pescatore (NEA) echoed and expanded on stated concerns regarding record retention in his paper "Preserving Records, Knowledge and Memory over Decades and More" using lessons learned from hazardous waste disposal. The paper concluded that loss of records is common, largely due to human factors. Another concern is that orders and established practices are followed without asking "what next?" Loss of records can also be impacted by financial factors; therefore, sufficient financial resources must be allocated. One of the comments from the attendees indicated that a lesson learned from when the Yucca Mountain project was closed down is that evolving electronic records systems can impact accessibility over time.

In the ninth paper, Gerhard Schmidt (Öko-Institut, Germany) discussed "Periodic Safety Review (PSR) in Interim Storage Facilities" based on the current regulations and experience in Germany. PSRs are consistently carried out for nuclear power plants, but until 2010, none had been performed for interim storage facilities in Germany. The paper concluded that the PSR as a holistic view on the facility's safety status allows the user to assess the effects over a ten-year period, identify safety issues, and improve the overall safety of the facility.

The Sellafield site in the UK comprises a wide range of nuclear facilities. Andrew Buchan (Sellafield Ltd, UK) discussed how a number of analysis techniques were used to establish a safety case for fault and accident conditions. The paper "The Safety Assessment of Long Term Interim Storage at Sellafield," illustrates how these analysis techniques were used to facilitate design, operation, resilience evaluation and accident management for facilities supporting long-term interim storage at Sellafield. Fukushima lessons learned were applied to the analysis. One conclusion is that, in the event of an emergency, personnel need simple guidance – there is no time in an emergency to read big documents.

The last paper of the session, "Introducing Systematic Aging Management for Interim Storage Facilities in Germany," was presented by Angelika Spieth-Achtnich (Öko-Institut, Germany). After summarizing the technical and regulatory background of interim storage in Germany, the paper identified some shortcomings in the applicable guidelines, including no mandatory PSR, and only very general provisions for addressing aging. A draft guideline has been updated to include all kinds of storage facilities, and to include a systematic aging management plan. This aging management plan also includes recommendations on non-technical aging issues such as knowledge management and long-term personnel planning. The paper concludes that the generation of information on aging can be an important basis for safety-relevant verifications for long-term storage.

Conclusions and Recommendations

Difficulties in developing and implementing safety requirements and the regulatory framework for long term storage and transportation of spent nuclear fuel can include: (1) the difference in licensing processes for storage and for transportation, (2) aging of dual purpose cask components, (3) traditional licensing approaches that do not consider long-term storage, (4) potential difficulties in repackaging stored spent fuel (for transportation or continued storage, (5) wide range of possibilities for final disposal (includes disposal media, disposal geology, and spent fuel packaging, etc), (6) impacts of higher burn-ups on retrievability, and (7) lack of systematic aging management programs.

Recommendations include:

(1) Base the safety case for final disposal on information gathered during interim storage.

(2) Preservation of records and knowledge management is a fundamental issue for long term storage.

(3) Do not leave unresolved questions for future generations.

(4) Storage concepts for very long term interim storage of spent fuel and high level waste must be developed given the delays in finding final repository solutions.

(5) Although already covered in Session 1, the need to develop Periodic Safety Reviews and Aging Management programs was again stressed.

Session 3: Technical issues & operational experience, needs for R&D

This session was chaired by Karl Wasinger (AREVA, Germany) and Fumihisa Nagase (JAEA, Japan).

Ten papers were presented during this session by representatives of research institutes of Japan (CRIEPI and JNES), Sweden (Studsvik Nuclear AB) and USA (SNL), independent experts acting on behalf of the safety regulatory body of Germany (BAM and TÜV), operators from France (AREVA) and Germany (GNS), and of the IAEA. The papers discussed the impact of extending storage periods, operational and licensing experiences in storage facilities, results of experiments, and identified necessary R&D to confirm safety of fuel and cask during the long-term storage.

Summary of papers

With the first paper, Evaristo J. Bonano (SNL, USA) concluded that long-term interim storage could either narrow the range of disposal solutions to direct disposal concepts or increase the risk that costly and hazardous re-packaging will be required. The paper suggests that eliminating needs for repackaging through direct disposal of large storage containers would substantially save cost and mitigate worker doses. Contributions from the floor focused mainly on local heat transmission to disposal sites and resulting pre-cooling requirements

Toshari Saegusa (CRIEPI, Japan) showed examples and proposals on ageing management, monitoring and inspection of spent fuel storage canister, based on their experimental data. Proposals included some ideas on monitoring confinement of canisters through measurement of temperature and doses at canister surfaces as well as a potential methodology to inspect SF integrity.

Information on experiences gained from long term dry storage at interim storage facilities at Ahaus and Gorleben was given by Lutz Oehlschläger (GNS, Germany). With this paper, the authors reported on cask

design and consideration of safety and licensing requirements and informed on inspections and PSA performed which demonstrated a high level of safety of the interim storage system used.

Various PIE techniques available at Studsvik Nuclear, especially related to the verification of the integrity of new cladding materials and the behaviour of new fuel designs for higher burnup during long term storage were then introduced by Joakim K.-H. Karlsson (Studsvik Nuclear AB, Sweden) followed by a paper presented by Herve Issard (AREVA, France) who reviewed current knowledge on spent fuel behaviour during storage and in transport after storage as particularly addressed by experiments performed under the Fuel Integrity Project (FIP). Herve Issard identified related data gaps and necessary research areas, and stated that there is a need for clarifying the time limit linked to cladding embrittlement eventually resulting in the need for repackaging for safety with special operation to achieve reprocessing and final disposal.

Tsutomu Hirose (JNES, Japan) introduced results of various integrity tests on mechanical property of irradiated fuel cladding and on dynamic load impact on HBU fuel rods considering regulatory judgment related to transportation without fuel inspection after long term dry storage.

The status of storage in Germany was then explained by Gerold Spykman (TÜV, Germany). Base on German acceptance criteria, issues to be considered for extending interim storage periods were identified and the importance of the management of data and knowledge was emphasized. For this purpose, a data management system specifically designed for this purpose was introduced.

Ken Sorenson of SNL introduced main results from the EPRI/Extend Storage Collaboration Program (ESCP) and reported that although needs for the extension of storage period and their priority are different among countries, consensus high priority gaps were identified mainly related to hydride effects and embrittlement of the fuel cladding, corrosion and stress corrosion cracking of the stainless steel canister, particularly in marine environments, and closure system degradation mechanisms.

As current delays in the selection of a disposal site in German will most likely result results in the need for extending current storage licenses originally granted for 40 years period. Under this point of view, Holger Völzke (BAM, Germany) summarized technical subjects for fuel integrity, safety evaluation of cask and ageing management to achieve safe long-term interim storage.

Concluding this session 3, Arturo Bevilacqua (IAEA) gave an overview on initial planning, agreements and contracts made for the Coordinated Research Project (CRP) on demonstrating performance of spent fuel and related storage systems beyond the long term. The paper informed on specific research objectives and gave an overview on future actions related to preparation of the final CRP report, in which the feedback received from the EPRI / ESCP program will be considered.

The outputs from session 3 are summarized as follows.

- The tendency to longer-term interim storage raises technical issues and consequently impacts the safety and costs of final disposal.

- There are data gaps for technical issues related to cladding integrity, such as cladding creep, DHC, stress evaluation, high burn-up effect and Helium release, as well as for cask integrity.

- Management of data and knowledge as well as ageing management itself are also important.

From the discussion of session 3, it is recommended that further analyses and investigations for the remaining technical issues are required to decrease data gap and consequently enhance knowledge and understanding of potential degradation mechanisms for further improvement of ageing management.

5. General Conclusions and Recommendations

Presentations and discussions at the workshop have shown that there is in many countries an interest or need for long term storage of spent nuclear fuel and high-level waste, before disposing in a final repository or reprocessing the used fuel. In some countries a prolongation of the storage period with respect to original planning is already anticipated. The main reasons are delays in site selection or planning and licensing of a final repository sometimes in combination with a national nuclear policy to abandon reprocessing of spent nuclear fuel from power reactors. Storage periods in the range of 50 to 100 years and even longer are being discussed. According to the objective of the workshop the presentations displayed the topics from different views of professional background and experience, i.e. facility operators, cask vendors, national authorities, experts involved in safety analyses and/or R&D activities and finally representatives from international organisations, who provided overview information on gained experience and on-going works in their member states as well as international cooperation programs.

Dry cask storage often using dual purpose casks, dry vault storage and wet pool storage were presented as the main storage concepts, currently applied or under development. From the presentations a preference for dry cask storage could be stated, but the discussion on this issue revealed specific advantages of both concepts. The major advantage of dry cask storage is seen in its reliance on passive components and robustness against external impacts. On the other hand pool storage provides direct access for monitoring and control of the stored fuel elements and higher flexibility for further steps of spent fuel management, e. g. packaging and/or conditioning of the fuel elements after storage. It was also addressed that use of passive cooling is a feasible option for wet storage as well. In any case the required level of safety has to be demonstrated and provided by appropriate measures in both storage types, dry and wet storage.

There is a number of different important aspects and challenges connected to long term storage having been illustrated in the presentations and highlighted in more detail in the discussions. These items can be assigned to the following four main topics:

- Technical aspects of ageing,
- Long term operational issues,
- Conceptual aspects of long term storage,
- Regulatory requirements, licensing and surveillance.

Regarding the technical aspects of ageing, the long term behaviour of the stored fuel and the performance of casks are the points of interest. As there is no direct access for monitoring of the fuel during cask storage, a demonstration of long term safety based on reliable data and experience is necessary. Current national practices of safety analyses and demonstration for licensing were presented, which are being approved usually for several decades. Results presented from international cooperation programs and gap analyses confirm the need for additional data and information on long term behaviour of the fuel cladding, in particular in the range 50 – 100 years and beyond, were the fuel temperature decreases, and also for high burn-up and mixed oxide fuel. Also data for material behaviour for cask components like metal gaskets, bolts of the lids and trunnions for lifting and transport are needed. In parallel also different methods of monitoring fuel behaviour and cask performance during storage are being developed and tested.

The second topic comprises all issues and tasks regarding long term operation of storage facilities. These are in particular ensuring knowledge management and qualification of operation personnel for more than several decades, record keeping on the stored material with regard to storage and for further use or disposal after storage, a systematic ageing management program as part of the safety management system, monitoring and analyses of operation experience. Also consideration of social aspects (e. g. public confidence and political commitment) has been identified as an important issue.

The topic 'conceptual aspects' is related at first to the question, which type of storage e. g. dry cask or wet pool storage should be preferred. As already mentioned there can be seen advantages and weaknesses in different storage types and a decision on the respective type of storage may besides safety also consider site specific conditions. Another important point is the holistic aspect of long term storage. In order to minimize the number of handling and conditioning processes and to avoid unnecessary radiation exposure to personnel, long term storage should be part of an integrated SF management concept e. g. use of multi-purpose cask for storage shipment and disposal.

The last but not less important topic comprises regulatory issues of long term storage. Important questions raised at the workshop concern the national approaches for licensing long term storage, e. g. for more than 50 years, time limitation of operational licenses, requirements for systematic ageing management, periodic safety review, demonstration and approval of transportability of spent fuel casks for the whole storage period and beyond, anticipated changes in national and international requirements, and finally observation of the (generally agreed) principle of not burdening unsolved problems of disposal to future generations.

Considering all these issues, which were presented and discussed with high expertise, from different points of view and based on different areas of experience but always objectively and unprejudiced, the following recommendations can be concluded:

Recommendations

The following recommendations were derived from the workshop, considering presentations, discussions and session summaries.

- Important regulatory aspects of long term storage like for instance time limitation of operation license, requirements for a safety case on long term storage, PSR, are compiled in the Specific Safety Guide SSG-15, issued recently by the IAEA.

- Long term storage, in general for 50 years and longer, should preferably be part of an integrated fuel/waste management program taking into account also the further use or treatment of the stored fuel/waste beyond storage. A license for long term storage should be periodically reviewed and integrated in the overall SF management, considering verification of long term safety and including social aspects. Appropriate margins and procedures for prolongation of an operation license should be provided.

- A holistic view of the whole process is needed, jointly analyzing all safety functions involved in all back-end stages up to final disposal, which would require a major regulatory effort. A license should as a minimum be connected to a commitment for developing further steps of SF management beyond storage within a certain short term.

- Regarding technical aspects of ageing, the deployment and progress should move towards closing the data gaps identified for long term behaviour of fuel rods and fuel cladding , in particular for high burn-up and MOx fuels and new cladding materials. Retrievability and transportability of the

fuel after storage is an important aspect. Also data on cask performance from on-going experiences and testing should be collected, evaluated and published.

- Sufficient adherence should be paid to the non-technical aspects of ageing, in particular knowledge management, record keeping of stored fuel/waste, personal training and planning.

- As both types of storage, wet and dry are providing specific advantages it is up to each country, to decide, which type of storage would be more favourable under the respective situation and condition.

- In order to assess mechanical behaviour of fuel rods such as hoop stress, creeping, effects of Hydrogen and/or temperature on cladding ductility, swelling of pellets etc. the availability of relevant experimental data would be useful for improving and validating calculations models and computer codes (e. g. TRANSURANUS, FRAPCON) for the long term range and for high burn-up fuel. Data for improving and benchmarking temperature calculation models for dry cask storage seems desirable as well.

- Appropriate solutions for long term storage of damaged fuel elements have to be developed.

- The delay in the final decision making results in lost opportunities for process optimization. Increasing the capacity of the pools and dry storages is not in the way of optimization.