LONG TERM STORAGE OF USED NUCLEAR FUEL IN THE U.S.

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Introduction

The U.S. has made the decision to cease further development of the Yucca Mountain Repository and pursue alternate advanced nuclear fuel cycles and disposal technologies. This will extend the current U.S. policy to store used fuel in-place (e.g., at the reactor sites) for decades to come. While the U.S. regulatory framework for storage is stable and U.S. utilities are experienced in both wet and dry storage, technical issues need to be addressed when considering long term storage of fuel that may extend well past 100 years.

In the U.S., storage licenses are issued for an initial period of 20 years, with the option to extend the storage term 2 times at 20 years each time. Therefore, the total allowable storage time for used fuel is 60 years. In theory, fuel could be stored in the pool for 60 years and then transferred to dry storage for an additional 60 years for a total of 120 years of out-of-reactor storage. In practice, utilities move used fuel out of pool storage earlier to dry storage to allow for continuous discharge of reactor fuel. The exception in the U.S. for this practice is the centralized pool storage facility in Morris, Illinois. This paper, therefore, will focus on long term dry storage of used fuel. Past 60 years, there is no technical basis for license extension. In addition to licensing storage systems past 60 years, there are associated regulatory issues with fuel retrievability and subsequent transportation after storage.

The U.S. Department of Energy (DOE) initiated a program in FY2009 to address the issues associated with long term storage of used fuel. The program is designed to work closely with industry and international organizations to develop a technical consensus of defining material degradation mechanisms, identifying the data needs, planning for the development of a demonstration facility to gather necessary data, and developing the technical basis documents that will be used to demonstrate the viability of very long term storage.

This paper will discuss the DOE program in the context of the larger national and international efforts currently being pursued.

Current U.S. Fuel Cycle Policy

The United States policy for the commercial nuclear fuel cycle has been one of once-through, direct disposal. Storage of used fuel has been on-site for the most part, using a combination of pool and dry cask storage systems. Licensing of dry storage is regulated through the U.S. Code of Federal Regulations, Chapter 10, Part 72 (1). With the anticipated licensing and operation of the Yucca Mountain Repository in the 2030 timeframe, the on-site storage of used fuel with a 60 year time horizon provided a sound programmatic and operational approach to managing once-through used fuel pending opening of the repository.

In November 2008, a new Administration was elected into the U.S. government. Part of its position relative to the commercial nuclear fuel cycle was that there must be a better way to disposition used nuclear fuel other than direct disposal at Yucca Mountain. Part of the reasoning behind this decision was that storage in-place of used fuel would be safe and secure for many years to come. This would allow the opportunity to evaluate advanced fuel cycles as well as better alternatives to Yucca Mountain. To explore fuel cycle alternatives, the Administration set up the Blue Ribbon Commission on America's Nuclear Future (BRC), whose charter is to explore all possible options to the nuclear fuel cycle and make recommendations to the Administration as to the best possible fuel cycle option(s) to pursue (2,3). The final report from the BRC is due to the DOE in January 2012.

A consequence of this decision is that the timeframe for on-site storage is extended well beyond the 60 years currently allowed in the regulations. Certainly, any final disposal option recommended by the BRC will be far in the future in terms of operations. This creates technical questions in terms of the used fuel currently in storage, as well as fuel that will be discharged from reactors in the future. Material degradation issues over very long periods of time must be understood in order to assure that the fuel in long term storage will retain its integrity and that the storage systems will maintain their vital safety functions.

Department of Energy Used Fuel Disposition Campaign

The DOE Office of Nuclear Energy (NE) is chartered to explore advanced fuel cycle initiatives in order to advance the use of commercial nuclear energy in a safe and secure manner. In addition, the focus is on development of the fuel cycle in a way that provides a sustainable uranium economy and that minimizes proliferation risks.

With the advent of the new Administration policy regarding the proposed Yucca Mountain Repository, NE began a new initiative in the Fuel Cycle Research and Development (FCR&D) program in FY09 to address issues associated with the very long term storage of fuel cycle materials. The Used Fuel Disposition (UFD) Campaign was formed under the FCR&D program to specifically address very long term storage of spent nuclear fuel as well as study generic repository concepts. While the charter of the UFD is to address all fuel types and wastes generated from candidate fuel cycles, the near-term effort for storage is focused on addressing very long term storage (VLTS) issues associated with LWR uranium oxide used fuel. Operational impacts resulting from any federal decision that defines the eventual fuel cycle and repository in the U.S. will occur decades in the future. Meanwhile, utility pool storage is rapidly reaching capacity in the U.S., creating a sustained drive to store used fuel on-site in dry storage. Now is the time to address technical issues regarding VLTS of LWR used fuel so that the regulatory position will be clear when the need arrives for time extensions beyond 60 years.

Under the UFD campaign, there are currently three work packages that define scope, budget, and schedule for conduct of work on used fuel storage. These are:

- Research and development (R&D) Opportunities
- Security
- Concept Evaluations

R&D Opportunities

For storage past 60 years, technical questions arise regarding fuel, cask/canister systems, and storage systems performance for extended periods of time. Guidance from the NRC is that these issues should be addressed for storage up to 300 years (4).

Fuel: 10CFR72.122 (1) requires that the fuel maintain integrity to prevent gross ruptures of the clad, resulting in potential operational safety problems when it is removed from storage. In addition to NRC regulations, guidance is provided by NRC in Interim Staff Guidance documents 1.2 and 11.3 (5, 6). These guidance documents reflect NRC concerns about material degradation under very long term storage conditions. Issues such as hydride re-orientation, hydride embrittlement, delayed hydride cracking, corrosion, plenum gas pressure, and creep must be addressed.

Cask/canister systems: In the U.S., dry cask storage designs include canistered as well as bare fuel configurations. Material property issues associated with neutron control and criticality prevention must be addressed. Long term performance of closure welds of canistered systems must be well understood, particularly for installations in marine environments that may accelerate stress corrosion cracking.

Storage systems: Overall performance of the entire storage system must be understood for these very long time frames. Concrete performance and degradation, rebar susceptibility to corrosion, overpack closure systems (e.g., seals and bolts), and performance of the pad must all be understood in order to demonstrate long term safety of these systems.

The objective of the R&D Opportunities work package is to identify the technical issues that have an impact on the potential licenseability of long term storage systems, identify analytical and experimental work to address the technical issues, prioritize the identified issues, perform the work necessary to address the technical issues and develop the technical documentation necessary to demonstrate safety over extended storage periods.

Preliminary identification of technical issues that may need to be addressed is shown in Table 1.

Table 1. Preliminary Research Priorities for Very Long Term Storage

System, Structure, Component	Degradation Mechanism	Influenced by Longer Times?	Influenced by Higher Burn-up?	Other Data Needs?	Priority of New Research
Cladding	Embrittlement - Radiation Induced - Annealing	Maybe	Maybe	Yes	Medium
	Embrittlement - Hydride Induced	Maybe	Yes	Yes	High
	Creep	Maybe	Maybe	Yes	Medium
	Delayed Hydride Cracking	Maybe	Yes	Yes	High
	Oxidation	Maybe	Maybe	Yes	Medium
Neutron shield	Loss of shielding	Maybe	Maybe	No	Very low

Container	Stress Corrosion Cracking of Closure Welds	Yes	No	Yes	High
	Degradation of Seals	Yes	No	Yes	Medium
	Marine Environment	Yes	No	Yes	High
Concrete overpack	Concrete Degradation	Yes	No	Yes	Low: potential for aging mgt program
Pad	Concrete Degradation	Yes	No	Yes	Low: potential for aging mgt program

These research priorities will be compared next year with a similar study being funded by the Nuclear Regulatory Commission. In addition, these priorities will be discussed with U.S. industry and international organizations in order to develop a consensus of the top priority research needs in this area.

Security

The objective of this work package is to identify and address security issues related to the VLTS of used fuel. While the security requirements are stable and consistent, there is fluidity in the threat environment that requires continual assessment of the adequacy of security of these materials. In addition, the DOE (7-10) and the NRC (11) have different requirements for the protection of used fuel in storage.

A major difference in the requirements of NRC versus DOE is the safeguards and security categorization of the material. The DOE uses a graded safeguards concept that takes into account the form of the material in determining the attractiveness. The NRC categorization is based totally on mass and for uranium, enrichment level. No consideration is given to the form of the material. For used fuel, this may not be an issue since in the past both NRC and DOE regulations have taken into account the "self-protection" afforded to SNF due to the extremely high dose rates. However, over long term storage, this self-protecting feature will diminish and the material will become more attractive to an adversary wishing to obtain nuclear material. Over time, the threat of theft may need to be addressed in addition to the threat of radiological sabotage.

Concept Evaluations

The objective of the Concept Evaluation work package is to integrate the identified needs of the R&D Opportunities and Security work packages into a comprehensive implementation plan that is focused on performing the work of gathering the identified required data to support development of the technical bases documents.

Specifically, the Concept Evaluation effort in FY10 identified preliminary alternatives for siting storage systems effectively in order to develop fuel performance data that may be needed to support technical basis development. Issues associated with this include licensing, facility testing capabilities (e.g., available hot cell work for post-irradiation examination), economics, and public support.

A number of alternative approaches could be used to acquire the necessary data. For this effort, four preliminary alternatives have been identified that span the spectrum of possibilities; from using existing fuels at existing sites with little testing capabilities to development of a stand-alone, licensed facility with the needed testing capabilities designed to accept different types of fuels and different dry cask storage systems. The four preliminary alternatives will be assessed against a set of criteria in order to evaluate on a relative basis the advantages and disadvantages of each alternative. Table 2 shows a matrix of the preliminary alternatives and how they might be evaluated against a set of criteria.

Table 2. Four Preliminary Demonstration Options and Associated Rating Critera

DEMONSTRATION OPTIONS				
	Existing ISFSI	**Modified ISFSI**	**Facility at a DOE Site**	**New Facility**
Siting and licensing	Licensed, may need NRC approval for operations	Licensed, may need NRC approval for operations	Operates under DOE orders	Licensing (or DOE permission) needed
Spectrum of UNF available	Limited	Full spectrum	Full spectrum	Full spectrum
Transportation requirements	Limited	Transportation of fuels needed	Transportation of fuels needed	Transportation of fuels needed
Testing requirements	Limited	Somewhat limited – transportation needed for testing	Generally available; available in DOE complex	Either transportation will be needed or facilities must be built
Construction/ operating cost	Minimal	Minimal	Moderate	High
Radiological controls	Adequate	Adequate	Adequate	Needed
Waste mgmt	Needed	Needed	Needed	Needed
Security	Adequate	Adequate	Adequate	Needed

These four alternatives and associated rating criteria will be discussed with industry in order to assess potential opportunities for collaboration with the industry in doing this work. It is anticipated that the final solution(s) will be a hybrid of the four alternatives and may include components of all of them.

Collaborative Activities

The DOE/NE program is designed to maximize collaborative opportunities. The DOE national laboratories have extensive capabilities, expertise, and experience in the areas of fuel performance, storage and transportation, and security. This capability spans analytical, experimental, and operational aspects of the fuel cycle. As such, Sandia National Laboratories, Pacific Northwest National Laboratory, Argonne National Laboratory, Idaho National Laboratory, and Savannah River Site all have significant roles in the three WPs discussed above. Work is allocated under the three WPs to these laboratories based on the fit between technical capability at the laboratory and technical issue that is being addressed.

This program is also actively collaborating with industry and the regulator through the Electric Power Research Institute (EPRI) Extended Storage Collaboration Program (ESCP). This program is designed to address technical issues associated with VLTS of used fuel. It is made up of representatives from industry, the NRC, and DOE. The ESCP is comprised of a Steering Committee, as well as a Methodology and an Experimental Subgroup. The objective of the Methodology Subgroup is to identify technical gaps that need to be addressed in order to demonstrate the safety of VLTS of used fuel. The objective of the Experimental Subgroup is to identify the means to conduct the work necessary to address the technical gaps. The structure of this program is designed to maximize collaborative interactions and to develop an understanding and general agreement of the main issues that need to be addressed to facilitate licensing of storage systems for up to 300 years.

An important component of the EPRI ESCP is engagement of the international community. Several countries have had long term storage R&D programs in-place for many years. Insights from these activities are important for licensing issues in the U.S. In aggregate, these efforts are designed to provide an understanding of the important technical issues relevant to licensing VLTS systems for used fuel. This collaborative approach will minimize redundancy, leverage existing good work, and provide confidence to the regulator and the industry that the appropriate R&D issues are being addressed.

Conclusion

This program is focused on the development of the technical documents needed to demonstrate the safety and security of storing used nuclear fuels for very long periods of time. This work, while being led by the U.S. Department of Energy, will engage with industry and international partners to;

- identify and prioritize the most important technical issues related to licensing,
- identify alternatives to conduct the research necessary to resolve the issues,
- identify fuels and facilities necessary to conduct the research,
- conduct the research, and
- write the technical documents

References

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(4) Nuclear Regulatory Commission COMSECY-10-0007, Project Plan for the Regulatory Program Review to Support Extended Storage and Transportation of Spent Nuclear Fuel, June 15, 2010.

(5) Nuclear Regulatory Commission Interim Staff Guidance – 1, Revision 2, Classifying the Condition of Spent Nuclear Fuel for Interim Storage and Transportation Based on Function, May 11, 2007.

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(11) U.S. Code of Federal Regulations, Chapter 10, Part 73, Physical Protection of Plants and Materials.