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Overview of the DOE Program Supporting the Very Long Term Storage and Transportation of Used Nuclear Fuel

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Background

The Department of Energy/Office of Nuclear Energy (DOE/NE) is supporting research and development to advance the understanding of material degradation mechanisms that may effect the safety and security of used nuclear fuel that has been in storage for long periods of time and that will eventually need to be transported after storage. The need for this work stems from the suspension of work on the proposed Yucca Mountain Repository and the resultant consequence of continuing to store used fuel in-place for the foreseeable future. It is expected that storage terms will last well beyond the regulatory maximum of 60 years.

The objective of the NE program is to support efforts related to development of technical basis documents needed to justify extended licensing of dry cask storage for up to 300 years, as well as justification of subsequent fuel retrieval and transportation. To achieve this objective, the NE program is divided into four distinct phases; R&D, Security, Transportation, and Concept Evaluations. Together, these phases will identify and prioritize the technical gaps that need to be addressed, as well as provide an assessment of how best to obtain the needed data. This effort will leverage modeling and simulation methods with experimental data to provide a comprehensive basis for making the necessary technical arguments. Integral to this program is a strong collaboration effort with U.S. industry as well as international organizations that have similar long term storage issues.

The remainder of this paper will discuss the status of each phase on a general level. Specific details of each phase are covered in subsequent papers.

R&D

The FY11 R&D effort has been focused on identification of technical gaps that need to be addressed to support licensing arguments for very long term storage of used nuclear fuel. The framework for the data gap analysis has been developed from a Systems Engineering perspective. Functional requirements were identified based on the regulations, criteria were defined to assess the importance of identified technical gaps as they relate to the functional requirements, and a deliberate qualitative method for assessing priorities was developed. Incumbent in this work was a comprehensive literature search to ensure that all technical work done to date on specific topic areas has been identified and assessed relative to its importance to understanding relevant material degradation mechanisms.

The technical gap analysis is focused on dry storage and covers all engineered components of the storage system; fuel and clad, canister, bolts and seals, overpack, and pad. Technical gaps are assessed for each of these components based on their importance to extended licensing. The potential range for addressing these gaps is broad; from development of aging management plans to properly monitor and assess system performance, to modeling and simulation of specific components, to experimental R&D.

Two other independent gap analyses are being performed in parallel with this effort. The Nuclear Regulatory Commission (NRC) and the Nuclear Waste Technical Review Board (NWTRB) are both conducting detailed analyses of potential technical gaps related to extended long term storage. Both of these organizations have release preliminary draft results. Preliminary results from the DOE effort track quite closely with these other two gap analyses.

The R&D gap analysis will be submitted as a high level deliverable to the DOE the end of June. Confidence in the identified technical gaps will be high as the results will tie directly to regulatory requirements and will be assessed relative to the NRC and NWTRB gap analyses.

Security

The security phase is focused primarily on identifying and assessing security concerns directly related to extended long term storage. One aspect of this is material attractiveness. As used fuel thermally and radioactively cools over a long period of time, the attractiveness of it changes for different attack scenarios. This implies potentially changing physical protection schemes at specific sites over time.

For example, used fuel is currently exempt from enhanced physical protection requirements stipulated in 10CFR73 if it has a dose rate > 100 Rem/hr at 1 meter. For typical used fuel in storage, dose rates will fall below this threshold between 70 and 120 years, depending on burnup. Once the dose rate goes below the threshold, one has to consider the mass of Special Nuclear Material (SNM) in the fuel in evaluating the physical protection requirements. The impact of added physical protection requirements could be significant in some cases.

A general approach being considered for assessing material attractiveness over long periods of time is called the Figure of Merit. This formulation assists in evaluating the proliferation resistance and physical protection requirements for material containing SNM. The Figure of Merit approach addresses three parameters incumbent in attractiveness considerations; mass of SNM, heat output, and dose rate. Work is continuing this year to assess the applicability of the Figure of Merit methodology to used fuel in long term storage.

In addition to material attractiveness, FY11 efforts include assessing security concerns specific to orphaned sites. While existing orphaned sites have approved security plans for the terms of their licenses, extended storage considerations may require physical protections measures that are different from those stipulated in the security plan due to the unique isolation characteristics of these sites.

Transportation

The transportation phase was initiated in FY11. The focus of this effort is to identify and address fuel integrity as it pertains to transportability after long term storage. This includes retrievability of the fuel from its storage configuration to a transportation configuration.

Technical issues related to clad integrity are similar to those that are being identified in the R&D phase for storage. Issues such as hydride embrittlement and creep are important to consider in terms of how they affect the ability of the fuel to withstand transportation environments. This is especially relevant for high burnup fuels.

In order to better understand the transport environment, a test plan is being developed to estimate loadings actually applied to the fuel. Giving the loadings, analyses can be conducted on the fuel with appropriate material properties to assess its ability to maintain its integrity during transport.

This phase is also evaluating the ability to use burnup credit for transport in order to maximize cask payloads by taking advantage of

the burnup of the fuel. This work is an extension of previous work done under the DOE Office of Civilian Radioactive Waste Management program.

Concept Evaluations

The Concept Evaluation phase is designed to integrate the technical efforts in the previous three phases to provide an assessment of candidate alternatives for acquiring the data and information needed to address the technical data gaps. This includes the evaluation of DOE and commercial facilities that have hot cell capabilities that will be needed to conduct destructive testing on used fuel segments.

This work can be viewed as having near-term and longer term aspects. Near-term experimental efforts will focus on obtaining data (e.g., hydride concentration and orientation) at initial conditions of storage. This is important so that change in material properties over time can be properly benchmarked to initial conditions. Longer term efforts may likely require a facility that hosts used fuel in actual storage conditions that can be accessed on an intermittent basis to monitor its condition.

Industry and International Collaborations

Collaboration with the industry and international organizations is mainly through participation on the Electric Power Research Institute (EPRI) Extended Storage Collaboration (ESCP) Program. ESCP is represented by industry (cask and fuel vendors, utilities, EPRI), the NRC as a regulator, and DOE national laboratories. The information exchanged is invaluable in understanding material degradation mechanisms as they relate to operational as well as regulatory perspectives.

An International Subcommittee was recently formed under ESCP to make sure that the international perspective is properly incorporated. Germany, Hungary, Japan, and the U.K. are currently actively involved in this subcommittee. Expansion of the subcommittee is expected as this work progresses. Investigations being done around the world can be leveraged to optimize work done in any one organization. For example, the Japanese have done extensive work on canister degradation in a marine environment. The Germans have active programs on bolt and seal performance associated with closure mechanisms in long term storage conditions. These are specific issues of concern in the U.S., as well.

Conclusion

The NE program is actively working to address technical issues associated with the long term storage and subsequent transportation of used nuclear fuel. In order to be most effective, this program is fully integrated with the U.S. regulator, commercial industry, and international organizations to ensure that all perspectives are considered and properly assessed. It is expected that this will be a multi-year program, but that useful data will be obtained in the next couple of years that will help to inform the multi-year program in a way that reduces program uncertainties and accelerates overall program progress.