AGING MANAGEMENT FOR HIGH BURNUP USED FUEL IN DRY STORAGE – A HOLISTIC APPROACH

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Commercial nuclear plants in the United States were originally designed with the expectation that used nuclear fuel would be moved directly from the reactor pools and transported off site for either reprocessing or direct geologic disposal. However, federal programs intended to meet this expectation were never able to develop the capability to remove used fuel from reactor sites – and these programs remain stalled to this day. Therefore, in the 1980s, with reactor pools reaching capacity limits, industry began developing dry cask storage technology to provide for additional on-site storage. Use of this technology has expanded significantly since then, and has today become a standard part of plant operations at most U.S. nuclear sites. Today, with no federal program yet on the horizon, it is evident that dry cask systems will be in use longer than originally envisioned and many storage systems now are coming due for license or certification renewal. In response to this challenge, a strong technical basis supporting long term dry storage safety has been developed. This technical basis includes not only the existing body of knowledge gained from the placement of over 2,000 dry storage systems into service over the past 28 years but also a forward-looking research and development component that will enable industry to address future challenges.

Industry has responded to one such challenge – the increasing prevalence of high burnup (HBU) used fuel in dry storage – with a confirmatory High Burnup Dry Storage Cask Research and Development Project (HDRP) designed to address the aging characteristics of HBU fuel storage, validate thermal analysis codes and obtain additional information about conditions following vacuum drying. The HDRP – jointly funded by the Department of Energy (DOE) and Electric Power Research Institute (EPRI) – involves loading a specially instrumented dry storage cask with a diverse collection of high burnup fuel, monitoring the condition of the fuel and cask in storage, and eventually transport the cask to a DOE site where it will be opened and the fuel examined. Loading the HDRP cask at Dominion's North Anna site is currently scheduled for 2017. The HDRP is also now being integrated into dry storage aging management programs at commercial power plant sites as part of the basis for the renewal of independent spent fuel storage installation licenses for periods beyond 20 years. This paper reports on the progress of the HDRP thus far, describes the role it is playing in license renewals, and highlights additional research and development needs going forward. The HDRP has become a central element of a comprehensive research and development portfolio supporting industry's goal of establishing a holistic approach to aging management.

I. INTRODUCTION

Since the first dry cask storage systems were loaded in 1986, this innovative solution has become one of the nuclear industry's most impressive success stories. To date, approximately 2000 dry cask systems have been safely loaded and are storing over 23,000 metric tons of used fuel, nearly a third of the total U.S. inventory[1]. These systems have protected public health and safety reliably and efficiently with no harmful release of radioactivity to the environment. Most of these systems are also designed to be transportable so that, once the federal government develops a location to accept used fuel, the fuel can be transported from the site without first having to repackage it for shipment.

At the same time that dry storage inventories were on the increase across the US, there were two parallel developments that would shape the environment in which dry storage aging management programs were developed – a series of legal proceedings and NRC rulemakings collectively referred to as "waste confidence" and changes in reactor operating practices that would result in higher fuel burnups on discharge.

I.A WASTE CONFIDENCE AND CONTINUED STORAGE

Beginning in 1984, the U.S. Nuclear Regulatory Commission (Commission or NRC), in response to a court ruling, began addressing the environmental impacts of used fuel accumulation on a generic basis. This was conducted through a succession of rulemakings (10 CFR Part 51) documenting the Commission's generic findings – known as the "Waste Confidence" findings. The original findings, and a subsequent update in 1990 and a review with no update in 1999, were supported both by progress in the development of a repository for final disposal at Yucca Mountain, Nevada and industry's demonstrated ability to store the material safely at reactor sites until Yucca Mountain would be ready.

In 2010, with the termination of the Yucca Mountain project, the NRC again updated its Waste Confidence findings. Reviewing the wealth of technical information that had been accumulated over a quarter of a century of dry storage experience, the Commission determined that used fuel could be safely stored at reactor sites for at least 60 years beyond the operating life of the reactor – which, when added to the 60 year operating life of most commercial reactors amounted to a statement that dry storage could be implemented for at least 120 years.

On June 8, 2012, the U.S. Court of Appeals for the District of Columbia, in response to suits brought by a number of states and other parties in the wake of the repository termination, remanded and vacated the Commission's 2010 Waste Confidence rule. The court found that NRC had not performed an adequate environmental evaluation in three specific areas, calling for additional analyses of potential reactor pool fires, pool leaks and impacts of a repository "never" being developed.

This court ruling had a significant effect on the licensing of new nuclear projects. On August 7, 2012 the Commission suspended the issuance of new or renewed reactor licenses until the court decision could be addressed. This process was completed, and the hold on new licenses lifted, in September 2014 when NRC replaced the Waste Confidence rule with a new Continued Storage rule in 10 CFR Part 51 along with an accompanying Generic Environmental Impact Statement (GEIS)[2]. This rule examined the environmental impacts of continuing to store used fuel at reactor sites for periods ranging from 60 years after the end of operating life to indefinite. The focus on potential indefinite storage has generated considerable regulatory and public interest in industry's efforts to assure long-term safety through effective aging management programs.

I.B HIGH BURNUP FUEL

As the dry storage industry was maturing, a separate trend was developing in reactor operations where fuel was being used in the reactors for longer periods of time. HBU fuel is typically defined as fuel that incurs an assembly average burnup in excess of 45,000 megawatt-days per metric ton uranium. The trend of increasing the discharge burnup of used fuel was enabled by the introduction of improved fuel designs with new, corrosion-resistant cladding materials. In the past few years this HBU fuel has cooled in pools to the point that it is now also being loaded into dry cask storage. Currently, approximately 450 casks have been loaded with HBU fuel[1] and almost all used fuel currently being discharged from reactors today is HBU fuel. The question of what, if any, special aging management considerations need to be addressed for HBU fuel is very much at the forefront of industry's efforts to assure long-term safety.

II. THE EXISTING TECHNICAL BASIS FOR LONG TERM STORAGE

Dry storage systems are robust structures with no moving parts. These systems incorporate multiple features to protect public health and safety. The foremost safety feature is the robust container itself: steel, steel-reinforced concrete, or steel-enclosed concrete. The containers are extremely rugged, using materials proven to be effective radiation shields. The makers of the systems design and test the containers to ensure they prevent the release of radioactive material even under the most extreme conditions, including earthquakes, tornadoes, hurricanes, and floods. The containers and their enclosures dissipate decay heat given off by the used fuel assemblies through well understood heat conduction methods and natural circulation cooling. The system is passive such that no power source is needed to keep the used fuel cool and safe. The containers are sealed and tested to a high standard of leak tightness to assure that the used fuel assemblies are maintained in a benign inert gas environment. Container internals are designed in accordance with established nuclear engineering principles to assure that an unintended nuclear criticality cannot occur.

Various dry storage container designs typically hold 21 to 87 used fuel assemblies – depending on specific fuel type and container design. To date, approximately 2,000 dry storage systems have been loaded and placed in service at 64 reactor sites in 35 states. Of the approximately 265,000 assemblies that have been discharged from commercial reactors in the U.S. industry's 50-year history, approximately 83,000 have been removed from pools and loaded into dry storage systems. The U.S. industry is loading about 7,800 assemblies into 160 containers each year. All of this has been accomplished safely, with no harmful release of radioactive material to the environment. By 2020, over 3,000 of these systems will be loaded at 76 locations.[1]

The inherent safety of dry storage systems, as well as the durability of the systems, has been recognized by the Nuclear Regulatory Commission (NRC). Dry storage at Independent Spent Fuel Storage Installations (ISFSIs) is licensed by the NRC; these licenses take one of two forms:

1. Site Specific Licenses under 10 CFR Part 72 – in this case a license is granted to a licensee previously authorized to possess used nuclear fuel under 10 CFR 50 (typically a reactor owner/operator) for a specific storage system to be deployed at a specific ISFSI site. License terms and conditions are specific to that system and site.
2. General Licenses under 10 CFR Part 72 – in this case a Certificate of Compliance (CoC) is granted to a licensee who designs, builds, and sells dry storage systems (typically a vendor) for a specific system that can be deployed at any ISFSI site owned/operated by a 10 CFR Part 50 licensee who is authorized to possess used nuclear fuel.

NRC's regulations originally called for the dry storage systems to be licensed or certified for 20 years, with an option for a 20-year renewal. Considering the extensive experience that has been gained since the first dry storage systems were put into service, the NRC in 2011 amended its independent spent fuel storage installation regulations to provide for a 40-year license with an option for a 40-year renewal[3]. In promulgating this extension, the Commission concluded "This increase is consistent with the NRC staff's findings regarding the safety of spent fuel storage as documented in the renewal exemptions issued to the Surry and H.B. Robinson ISFSIs[a]"[3] . Similarly, the Commission in 2010 concluded "studies performed to date have not identified any major issues with long-term use of dry storage"[4]. This conclusion was given further support in NRC's 2014 GEIS[2]. Given that 70 percent of U.S. reactors are licensed for operation up to 60 years, the NRC has expressed confidence that it is safe to store used nuclear fuel at reactor sites for up to 120 years without repackaging the fuel.

Perhaps the most significant demonstration of dry storage system longevity was provided by the Dry Storage Characterization Project completed in August of 2001. This project opened a Castor V/21 cask stored from 1985 to 1999 and verified that "long-term storage has not caused detectable degradation of the spent fuel cladding or the release of gaseous fission products"[6].

Finally, the confidence in the safety of dry storage provided by these studies is also shared by the general public. A February 2012 public opinion survey found that 64 percent of Americans believe that storing used nuclear fuel at reactor sites is safe[7].

III. ADDRESSING FUTURE CHALLENGES – HIGH BURNUP FUEL

Even though the entrance of HBU fuel into the dry storage marketplace is relatively recent[b], industry and NRC have already begun to proactively re-examine the established technical basis for long term storage to factor in the increasing prevalence of HBU fuel. Programs have been developed to examine the aging characteristics of HBU fuels of multiple cladding types to confirm that the conclusions of previous studies can continue to be supported as these fuels begin to conclude their first decade in dry storage. These programs are timely because most of the low burnup fuel previously discharged has already been loaded into dry storage, meaning most future dry storage loadings will include HBU fuel.

Several dry storage facilities at which HBU fuels are stored have either recently completed, are in the midst of, or will soon be due for license renewal (see Table 1). In order to obtain renewal, facility operators are committing to aging management programs to address questions about whether or not the conclusions already reached for long term storage of low burnup fuel remain valid for HBU fuels.

[a] The Surry and Robinson nuclear power plants were the first two dry cask storage facilities (ISFSIs) to receive 40 year license renewals

[b] The majority of HBU fuel in dry storage has been loaded in the past 6 years, with only a small amount having been loaded 7 to 9 years ago

Table 1. Licenses for high burn-up fuel storage recently renewed or to be renewed over next six years

Year Renewal Due	License to be renewed (Type of License)	Status
2012	Calvert Cliffs-NUHOMS[c] (Site Specific)	Renewal to 2052 granted in Oct. 2014
2012	Prairie Island-TN-40 (Site Specific)	Renewal Pending
2015	Transnuclear-NUHOMS 1004 (General)	Renewal Application submitted to NRC in Nov. 2014
2020	NAC-UMS; Holtec-HI-STORM (General)	

In anticipation of the need for confirmatory scientific and technical work to support the aging management plans that would be part of these dry storage license and certificate renewals, in 2009 the Electric Power Research Institute (EPRI) organized the Extended Storage Collaboration Program (ESCP) to share information and data related to long-term storage of used nuclear fuel and transportation following extended storage. ESCP is an international partnership between industry, government, and scientific organizations that is conducting work in three stages:

1. Identify technical data gaps that need to be addressed to project the longer-term evolution of dry storage and transportation systems including the used fuel.
2. Conduct small-scale testing, develop models, perform field inspections, and conduct small-scale, longer-term testing.
3. Develop and conduct one or more full-scale confirmatory demonstration project(s)

IV. THE HBU FUEL DRY CASK STORAGE DEMONSTRATION PROJECT (HDRP)

Perhaps the most significant project to have originated from ESCP is the High Burnup Dry Storage Cask Research and Development Project (HDRP). The HDRP is an EPRI led project, co-funded by EPRI and DOE, which is being implemented with the involvement of a number of industry partners and with support from several national laboratories. The HDRP is an important and timely supporting element of the ongoing dry storage license renewal process. Even though the first license renewals for dry storage systems containing HBU fuel are coming due now (as shown in Table 1), the length of time that HBU fuel has actually been stored in these systems is still relatively short (less than 10 years). Therefore, there is still ample time to collect data on the aging of HBU fuel in storage to validate models and analysis that will predict its longer term performance before any HBU fuel has actually been in storage for periods of time significantly exceeding the original 20 year licensed period of the storage systems. However, it is important that industry begin collecting this data as soon as possible, because some HBU fuel is now nearing the end of its first decade in storage. An important step towards meeting this important data collection need was taken in February 2014 with the finalization of the Test Plan for the HDRP[8] and the commencement of design work on the project.

The HDRP will provide industry with prototypical information for use in aging management programs as an alternative to reopening casks to examine fuel at numerous individual sites. The HDRP will be similar to the previously discussed project that opened and examined lower burn-up fuel (less than 35 GWD/MTU) stored in dry casks at Idaho National Lab. However, the HDRP includes a dry storage cask that will be instrumented in advance at the reactor site to gather data as soon as it is loaded. The data collected over the first few years of the project will be highly valuable in establishing a realistic assessment of the conditions the fuel experiences in storage.

The Test Plan for the HDRP[8] outlines the data to be collected; the HBU fuel to be included; and the storage system design, procedures, and licensing necessary to implement the project. The main goals of the proposed test are to provide confirmatory data for model validation, facilitate model improvement, assess storage system drying effectiveness, provide input to future dry storage system design, support new and renewed ISFSI licenses, and support transportation licensing for HBU fuel.

To provide data that is most relevant to HBU fuel in dry storage, the design of the test storage system will closely mimic real conditions that HBU fuel experiences during all stages of dry storage: loading, cask drying, inert gas backfilling, and transfer to the ISFSI for multi-year storage. A TN-32 bolted lid cask (the Research Project Cask or RPC) will be loaded with intact HBU fuel with four different kinds of cladding at Dominion Virginia Power's North Anna Power Station (North Anna): standard Zircaloy-4, low-tin Zircaloy-4, Westinghouse Zirlo™, and Areva M5™. All the HBU fuel to be loaded into the cask is already present in the North Anna spent fuel pool. The TN-32 lid will be modified to allow insertion of temperature probes inside the cask at various axial and radial locations for real-time temperature

[c] Since 1992, allowable burn-up to 47 GWd/MTU, since 2010, up to 52 GWd/MTU

monitoring. Cask cavity gas samples will be obtained periodically for analysis of oxygen and hydrogen content, moisture content, and for the presence of any fission gases. Several TN-32 casks have already been loaded at North Anna. Hence, Dominion has both licensing and operational experience with TN-32 casks.

Prior to loading the RPC with HBU fuel assemblies, up to 25 fuel rods (also referred to as "sister rods") will be removed, prepared for shipment using normal, approved vacuum-drying procedures, and shipped to a national laboratory for detailed non-destructive and destructive examination. These 'sister rods' have similar characteristics to those that will be stored in the RPC and will be taken from either assemblies having similar operating histories (symmetric partners) to those that are selected for storage in the RPC or actual fuel assemblies to be included in the RPC [d]. The detailed hot cell examinations at the national laboratory will provide essential information on the physical state of the HBU rods and the fuel contained in the rods prior to the loading, drying, and long-term dry storage process.

Phase I of the project consists of designing cask modifications, selecting fuel for storage, modifying the cask, obtaining regulatory approval from NRC, loading the cask, and beginning monitoring activities. The schedule for these activities is described in Table 2 below. Carrying out the activities in accordance with the schedule is contingent on a number of factors, including obtaining NRC license amendments in a timely manner and receiving adequate funding from DOE for the work.

It is anticipated that the RPC will be loaded in 2017 and will remain at the North Anna ISFSI for approximately 10 years. Phase I of the HDRP completes in 2018 so subsequent work is outside the scope of the initial contract. Nevertheless, plans are to continually monitor cask temperatures during storage, and to periodically sample the gas inside the cask to determine if any moisture is present and if any fuel rods have leaked. Additional work will also include obtaining NRC regulatory approval to transport the cask. In the 2027 time frame the cask will be shipped to a yet-unidentified facility where it will be opened in a dry environment[e] in order to ascertain the conditions of the contents. Some rods will be removed from the stored fuel and detailed hot cell examinations will be performed. Following the cask and fuel examination, the cask will be re-closed and stored, enabling the acquisition of additional data.

Table 2. HDRP Schedule

Year	Project Milestones
2014	Completion of test plan and beginning of design and procurement efforts.
2015	Beginning of modifications to cask lid. Completion of design basis licensing document. Submittal of the storage license amendment application to NRC.
2016	Ship sister rods to a national laboratory for evaluation. Address NRC requests for additional information. Ship the RPC including modified lid, to North Anna.
2017	Obtain NRC license. Perform dry runs. Load the RPC and begin temperature and gas data collection during the drying process. Move the loaded cask to the North Anna ISFSI
2018	Continuation of data collection activities and completion of some calculations to support future transportation
TBD	The schedule for transportation of the RPC to a DOE operated hot cell for opening and examination of stored fuel assemblies will be determined by a follow-on, phase II contract

V. THE HDRP's ROLE IN DRY STORAGE LICENSE RENEWAL

As information/data from a fuel performance surveillance demonstration program becomes available, licensees will monitor, evaluate, and trend the information via their Operating Experience Program and/or the Corrective Action Program to determine what actions should be taken to manage fuel and cladding performance, if any.

Formal evaluations of the aggregate feedback from the HDRP and other sources of information will be performed at specific points in time during the period of extended operation. Dry storage licensees and CoC holders make regulatory commitments to perform these evaluations by including them as "toll gates" in the aging management plans (AMPs) that are required at the time of license renewal. An example of a "toll gate" AMP is shown below as Table 3. These evaluations will include an assessment of the continued ability of the high burnup fuel assemblies to continue to perform their intended function(s).

[d] If rods are removed from assemblies stored in the RPC, those rods will be replaced by dummy rods.

[e] While it is certainly possible to open the RCP underwater in order to access and examine the used fuel, there are concerns that the re-wetting process could impact the state of the fuel (and in particular the cladding), detracting from the value of the data.

Table 3. Example Toll Gate

Toll Gate	Year	Assessment
1	2028	Evaluate information obtained from the HDRP loading and initial period of storage along with other available sources of information. If the HDRP non-destructive evaluation (NDE) – i.e., cask gas sampling, temperature data) has not been obtained at this point and no other information is available then the licensee has to provide evidence to the NRC that no more than 1% of the HBF has failed.
2	2038	Evaluate, if available, information obtained from the destructive (DE) and non-destructive (NDE) examination of the fuel placed into storage in the HDRP along with other available sources of information. If the aggregate of this information confirms the ability of the high burnup fuel assemblies to continue to perform intended function(s) for the remainder of the period of extended operations, subsequent assessments may be cancelled. If the HDRP DE of the fuel has not been examined at this point and no other information is available then the licensee has to provide evidence to the NRC by opening a cask or single effects surrogate experiments that the fuel performance acceptance criteria 1-4 in element 6 of the Aging Management Program continue to be met.
3	2048	Evaluate any other new information.

VI. NEXT STEPS

As mentioned, the initial design work on the HDRP is already under way and activities to be performed during the first five years of the project have been defined. Data gathered in HDRP Phase I will provide significant insights into loading and storing high burnup fuel in prototypical conditions. Phase II activities will culminate in detailed examination of the stored fuel. However, some years ago DOE elected to shut down its large hot cell facility at Test Area North of the Idaho National Laboratory in which casks from the earlier dry storage characterization project had been opened. Accordingly, there is currently no United States facility capable of receiving and opening the RCP in a dry environment in order to examine the contents. DOE is working to identify a facility at a DOE site that can be modified to accomplish the cask unloading and thereby accomplish Phase II work.

Data from HDRP Phase I and Phase II will provide insights into the dry storage environment and the state of high burnup fuel cladding following loading and storage. In addition, dry storage heat transfer models will be validated against actual temperature data, providing additional information about realistic cask conditions and likely demonstrating significant additional safety margin.

Furthermore, the HDRP is just the beginning of a crucial, longer term program. It is important that DOE, with industry input, develop a comprehensive, workable plan to support the long-term success of dry storage. This plan would not just benefit current dry storage programs and licensing, but would be integral to key scientific programs that support research and development of fuel stored and materials used in a future repository. Part of this plan would be to develop a hot cell that will readily accommodate full-size storage systems to allow removal of the fuel payload for subsequent fuel destructive testing and examination of storage system materials after storage (such as that required for Phase II of the HDRP, described above). While much is already understood about the behavior of fuel and materials, this facility would provide the foundational framework for R&D to confirm the long-term viability of fuel in storage and lead to a better understanding of fuel to be permanently emplaced in a repository.

Ideally, this facility should be located at a national laboratory which already has an existing infrastructure to perform many of the needed tests. Another option for this facility would be to construct it as part of a consolidated interim storage facility which will need to have fuel storage system handling and packaging functionality as part of its normal operations. In this scenario, fuel assemblies could be removed (or rods removed) and sent to a national laboratory for further examination.

This facility would be a key component in a long-term, comprehensive DOE strategy to assist industry in resolving issues associated with long term dry storage of its fuel. In this regard, the aging of HBU fuel is not the only consideration. A comprehensive program to acquire confirmatory data and inform aging management plans must consider all aspects of dry storage – not just HBU fuel stored in bolted lid systems, but also the canisters and overpacks in which they are stored for welded canister systems.

Regarding welded canister systems, industry believes that, over the long-term, emphasis should shift to the stainless steel canisters (rather than the cladding) as the primary means of confining radionuclides and thereby assuring public health and safety. In this regard, EPRI has already begun a program of canister inspections. Industry is also committed to assuring that the same level of effort now being put into the HDRP is carried over into all elements of such a comprehensive program and is committing to forward-looking canister inspection programs as part of the aging management programs supporting dry storage license renewal.

Efforts to evaluate the condition of HBU fuel in long term storage and assure the long term integrity of stainless steel dry storage canisters are just two of the most prominent examples of the industry's holistic approach to aging management. These programs will ensure that industry can continue to manage UNF safely as necessary until the federal government develops a disposal solution. Industry has recently proposed, for NRC consideration, license renewal guidance[9] to assure that this approach is applied consistently across the dry storage fleet. This same approach is a core element of each of the recently approved and pending renewal applications mentioned in Table 1.

Given the relatively recent termination of work on the Yucca Mountain repository project, a DOE decision that effectively postponed indefinitely the already overdue disposal of used fuel, industry expects that a comprehensive program to confirm the longevity of dry storage will be a major mission focus for the federal government.

VII. CONCLUSION

Throughout the 50 year history of commercial nuclear energy production, the U.S. nuclear industry has been highly adept at adapting to changing conditions. One area in which such adaptation has been most necessary has been in response to the uncertainties of the nation's federal used fuel management program, which began with an emphasis on reprocessing, then promised a geologic repository by 1998, then delayed the repository several times, and now is stalled for an indeterminate period of time. Dry used fuel storage, deployed in response to these changes in the federal program, has been one of the industry's most innovative and successful adaptation mechanisms.

Industry is now building on this success, and again proactively working on innovative solutions to assure that dry storage can continue to be relied on well into the future. The HDRP is a major step in this adaptation process. The project is off to a successful start and commitments to apply information gained from it are already being built into aging management programs supporting dry storage license renewal. However, much work remains to be done in terms of putting in place the infrastructure needed to fully complete this project, as well as to assure that the research and development capability for a broader range of dry storage aging management projects is established and maintained.

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REFERENCES

1. Gutherman Technical Services, June 2014 Used Fuel Data, Letter Gutherman to Cummings, July 25, 2014
2. 79 Fed. Reg. 56238, September 19, 2014
3. 74 Fed. Reg. 8874, February 16, 2011
4. 75 Fed. Reg. 81072, December 23, 2010
5. USNRC, Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel, NUREG-2157, September 2014
6. Dry Cask Storage Characterization Project – Phase 1:CASTOR V/21 Cask Opening And Examination, W.C. Bare and L.D. Turgeon, August 2001, INEEL/EXT-01-00183, Revision 1
7. Bisconti Research 2012
8. EPRI, High Burnup Dry Storage Cask Research and Development Project, Final Test Plan, Rev. 0, February 27, 2014
9. NEI 14-03, Guidance for Operations-Based Aging Management for Dry Cask Storage, letter from McCullum to Lombard, September 23, 2014