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## Spent Fuel Storage in Pools and Dry Casks Key Points and Questions & Answers

### Key Points:

All U.S. nuclear power plants store spent nuclear fuel in “spent fuel pools.” These pools are robust constructions made of reinforced concrete several feet thick, with steel liners. The water is typically about 40 feet deep, and serves both to shield the radiation and cool the rods.

As the pools near capacity, utilities move some of the older spent fuel into “dry cask” storage. Fuel is typically cooled at least 5 years in the pool before transfer to cask. NRC has authorized transfer as early as 3 years; the industry norm is about 10 years.

The NRC believes spent fuel pools and dry casks both provide adequate protection of the public health and safety and the environment. Therefore there is no pressing safety or security reason to mandate earlier transfer of fuel from pool to cask.

After the September 11, 2001, terrorist attacks, the NRC issued orders to plant operators requiring several measures aimed at mitigating the effects of a large fire, explosion, or accident that damages a spent fuel pool. These were meant to deal with the aftermath of a terrorist attack or plane crash; however, they would also be effective in responding to natural phenomena such as tornadoes, earthquakes or tsunamis. These mitigating measures include:

Controlling the configuration of fuel assemblies in the pool to enhance the ability to keep the fuel cool and recover from damage to the pool.

Establishing emergency spent fuel cooling capability.

Staging emergency response equipment nearby so it can be deployed quickly

According to the Congressional Research Service (using NEI data), there were 62,683 metric tons of commercial spent fuel accumulated in the United States as of the end of 2009.

Of that total, 48,818 metric tons – or about 78 percent – were in pools.

13,856 metric tons – or about 22 percent – were stored in dry casks.

The total increases by 2,000 to 2,400 tons annually.

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## Questions and Answers – General

### What is spent nuclear fuel?

“Spent nuclear fuel” refers to fuel elements that have been used at commercial nuclear reactors, but that are no longer capable of economically sustaining a nuclear reaction. Periodically, about one-third of the nuclear fuel in an operating reactor needs to be unloaded and replaced with fresh fuel.



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### Why does spent fuel need to be cooled?

Spent fuel continues to generate heat because of radioactive decay of the elements inside the fuel. After the fission reaction is stopped and the reactor is shut down, the products left over from the fuel's time in the reactor are still radioactive and emit heat as they decay into more stable elements. Although the heat production drops rapidly at first, heat is still generated many years after shutdown. Therefore, the NRC sets requirements on the handling and storage of this fuel to ensure protection of the public and the environment.

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## Questions and Answers – Spent Fuel Inventories

### Why doesn't the NRC have up-to-date figures on how much spent fuel is stored at U.S. nuclear plants?

The NRC and Department of Energy (NNSA) operate the Nuclear Material Management and Safeguards System (NMMSS), a database that tracks Special Nuclear Material (enriched uranium and plutonium). This database does not distinguish between fresh and irradiated material, and the information is withheld from the public for security reasons. That's why figures on spent fuel inventory come from the industry.

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### How much fuel is currently in dry cask storage?

As of November 2010, there were 63 “independent spent fuel storage installations” (or ISFSIs) licensed to operate at 57 sites in 33 states. These locations are shown on a map on the NRC website at: <http://www.nrc.gov/waste/spent-fuel-storage/locations.pdf>. Over 1400 casks are stored in these independent facilities.

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### How much fuel is stored at decommissioned reactors? Is it in pools or casks?

There are currently 10 decommissioned nuclear power reactors at 9 sites with no other nuclear operations. According to a 2008 Department of Energy report to Congress, approximately 2800 metric tons of spent fuel is stored at these nine sites. As of the writing of that report, seven of the sites had independent spent fuel storage installations, or ISFSIs. Two additional sites had approximately 1000 metric tons of spent fuel remaining in pool storage.

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## Questions and Answers – Spent Fuel Pool Safety

### What do you look at when you license a fuel storage facility? How do I know it can withstand a natural disaster?

The NRC's requirements for both wet and dry storage can be found in Title 10 of the Code of Federal Regulations (10 CFR), including the general design criteria in Appendix A to Part 50 and the spent-fuel storage requirements in Part 72. The staff uses these rules to determine that the fuel will remain safe under anticipated operating and accident conditions. There are requirements on topics such as radiation shielding, heat removal, and criticality. In addition, the staff reviews fuel storage designs for protection against:

- natural phenomena, such as seismic events, tornados, and flooding
- dynamic effects, such as flying debris or drops from fuel handling equipment and drops of fuel storage and handling equipment
- hazards to the storage site from nearby activities



## **How do you know the fuel pools are safe? Does the NRC inspect these facilities, or just the reactor itself?**

NRC inspectors are responsible for verifying that spent fuel pools and related operations are consistent with a plant's license. For example, our staff inspects spent fuel pool operations during each refueling outage. We also performed specialized inspections to verify that new spent fuel cooling capabilities and operating practices were being implemented properly.



## **What would happen to a spent fuel pool during an earthquake? How can I be sure the pool wouldn't be damaged?**

All spent fuel pools are designed to seismic standards consistent with other important safety-related structures on the site. The pool and its supporting systems are located within structures that protect against natural phenomena and flying debris. The pools' thick walls and floors provide structural integrity and further protection of the fuel from natural phenomena and debris. In addition, the deep water above the stored fuel (typically more than 20 feet above the top of the spent fuel rods) would absorb the energy of debris that could fall into the pool. Finally, the racks that support the fuel are designed to keep the fuel in its designed configuration after a seismic event.



## **Can spent fuel pools leak?**

Spent fuel pools lined with stainless steel are designed to protect against a substantial loss of the water that cools the fuel. Pipes typically enter the pool above the level of the stored fuel, so that the fuel would stay covered even if there were a problem with one of the pipes. The only exceptions are small leakage-detection lines and, at two pressurized water reactor (PWR) sites, robust fuel transfer tubes that enter the spent fuel pool directly. The liner normally prevents water from being lost through the leak detection lines, and isolation valves or plugs are available if the liner experiences a large leak or tear.



## **How would you know about a leak in such a large pool of water?**

The spent fuel pools associated with all but one operating reactor have liner leakage collection to allow detection of very small leaks. In addition, the spent fuel pool and fuel storage area have diverse instruments to alert operators to possible large losses of water, which could be indicated by low water level, high water temperature, or high radiation levels.



## **How can operators get water back in the pool if there is a leak or a failure?**

All plants have systems available to replace water that could evaporate or leak from a spent fuel pool. Most plants have at least one system designed to be available following a design basis earthquake. In addition, the industry's experience indicates that systems not specifically designed to meet seismic criteria are likely to survive a design basis earthquake and be available to replenish water to the spent fuel pools. Furthermore, plant operators can use emergency and accident procedures that identify temporary systems to provide water to the spent fuel pool if normal systems are unavailable. In some cases, operators would need to connect hoses or install short pipes between systems. The fuel is unlikely to become uncovered rapidly because of the large water volume in the pool, the robust design of the pool structure, and the limited paths for loss of water from the pool.



## **Do U.S. nuclear power plants store their fuel above grade? Why is this considered safe?**

For boiling water reactor (BWR) Mark I and II designs, the spent fuel pool structures are located in the reactor building at an elevation several stories above the ground (about 50 to 60 feet above ground for the Mark I reactors). The spent fuel pools at other operating reactors in the U.S. are typically located with the bottom of the pool at or below plant grade level. Regardless of the location of the pool, its robust construction provides the potential for the structure to withstand events well beyond those considered in the original design. In addition, there are multiple means of restoring water to the spent fuel pools in the unlikely event that any is lost.



## **How are spent fuel pools kept cool? What happens if the cooling system fails?**

The spent fuel pool is cooled by an attached cooling system. The system keeps fuel temperatures low enough that, even if cooling were lost, operators would have substantial time to recover cooling before boiling could occur in the spent fuel pool. Licensees also have backup ways to cool the spent fuel pool, using temporary equipment that would be available even after fires, explosions, or other unlikely events that could damage large portions of the facility and prevent operation of normal cooling systems. Operators have been trained to use this backup equipment, and it has been evaluated to provide adequate cooling even if the pool structure loses its water-tight integrity.



## **What keeps spent fuel from re-starting a nuclear chain reaction in the pool?**

Spent fuel pools are designed with appropriate space between fuel assemblies and neutron-absorbing plates attached to the storage rack between each fuel assembly. Under normal conditions, these design features mean that there is substantial margin to prevent criticality (i.e., a condition where nuclear fission would become self-sustaining). Calculations demonstrate that some margin to criticality is maintained for a variety of abnormal conditions, including fuel handling accidents involving a dropped fuel assembly.



## **Questions and Answers – ISFSIs**

### **What is dry cask storage?**

Dry cask storage allows spent fuel that has already been cooled in the spent fuel pool for several years to be surrounded by inert gas inside a container called a cask. The casks are typically steel cylinders that are either welded or bolted closed. The steel cylinder provides containment of the spent fuel. Each cylinder is surrounded by additional steel, concrete, or other material to provide radiation shielding to workers and members of the public.



### **What is an "ISFSI"?**

An independent spent fuel storage installation, or ISFSI, is a facility that is designed and constructed for the interim storage of spent nuclear fuel. These facilities are licensed separately from a nuclear power plant and are considered independent even though they may be located on the site of another NRC-licensed facility.



## **What kind of license is required for an ISFSI?**

NRC authorizes storage of spent nuclear fuel at an ISFSI in two ways: site-specific or general license. For site-specific applications, the NRC reviews the safety, environmental, physical security and financial aspects of the licensee and proposed ISFSI and, if we conclude it can operate safely, we issue a license. This license contains requirements on topics such as leak testing and monitoring and specifies the quantity and type of material the licensee is authorized to store at the site. A general license authorizes storage of spent fuel in casks previously approved by the NRC at a site already licensed to possess fuel to operate a nuclear power plant. Licensees must show the NRC that it is safe to store spent fuel in dry casks at their site, including analysis of earthquake intensity and tornado missiles. Licensees also review their programs (such as security or emergency planning) and make any changes needed to incorporate an ISFSI at their site. Of the currently licensed ISFSIs, 48 are operating under general licenses and 15 have specific licenses.



## **Questions and Answers – Dry Cask Safety**

### **How do you know the dry casks are safe? Does the NRC inspect these facilities, or just the reactor and spent fuel pool?**

The NRC is responsible for inspection of dry cask storage. All casks also undergo a safety review before they are certified for use by the NRC. Before casks are loaded, inspectors with specific knowledge of ISFSI operations assess the adequacy of a “dry run” by the licensee; they then observe all initial cask loadings. The on-site resident inspectors or region-based inspectors may observe later cask loadings, and the regional offices also perform periodic inspections of routine ISFSI operations.



### **What keeps fuel cool in dry casks?**

The fuel is cooled by natural airflow around the cask. Fuel is often moved to dry cask storage after several years in spent fuel pools, so the heat given off by the fuel has significantly decreased.



## **Questions and Answers – Waste Confidence & Future Plans**

### **How long is spent fuel allowed to be stored in a pool or cask?**

NRC regulations do not specify a maximum time for storing spent fuel in pool or cask. The agency’s “waste confidence decision” expresses the Commission’s confidence that the fuel can be stored safely in either pool or cask for at least 60 years beyond the licensed life of any reactor without significant environmental effects. At current licensing terms (40 years of initial reactor operation plus 20 of extended operation), that would amount to at least 120 years of safe storage.

However, it is important to note that this does not mean NRC “allows” or “permits” storage for that period. Dry casks are licensed or certified for 20 years, with possible renewals of up to 40 years. This shorter licensing term means the casks are reviewed and inspected, and the NRC ensures the licensee has an adequate aging management program to maintain the facility.



### **The most recent waste confidence findings say that fuel can be stored safely for 60 years beyond the reactor's licensed life. Does this mean fuel will be unsafe starting in 2059 [60 years after**

## **Dresden 1's original license ended]? What if the spent fuel pool runs out of room even before the end of a reactor license? What is the NRC going to do about this?**

The NRC staff is currently developing an extended storage and transportation (EST) regulatory program. One aspect of this program is a safety and environmental analysis to support long-term (up to 300 years) storage and handling of spent fuel, as well as associated updates to the “waste confidence” rulemaking. This analysis will include an Environmental Impact Statement (EIS) on the environmental impacts of extended storage of fuel. The 300-year timeframe is appropriate for characterizing and predicting aging effects and aging management issues for EST. The staff plans to consider a variety of cask technologies, storage scenarios, handling activities, site characteristics, and aging phenomena—a complex assessment that relies on multiple supporting technical analyses. Any revisions to the waste confidence rulemaking, however, would not be an “approval” for waste to be stored longer than before—we do that through the licensing and certification of ISFSIs and casks. More information on the staff’s plan can be found in SECY-11-0029.

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## **Does the waste confidence decision mean that a particular cask is safe?**

Not specifically. When the NRC issues of certificates and licenses for specific dry cask storage systems, the staff makes a determination that the designs provide reasonable assurance that the waste will be stored safely for the term of the license or certificate. The Commission’s Waste Confidence Decision is a generic action where the Commission found reasonable assurance that the waste from the nation’s nuclear facilities can be stored safely and with minimal environmental impacts until a repository becomes available.

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## **The waste-confidence revision seems like a long-term effort. What is the NRC doing to improve safety of spent fuel storage now?**

The NRC staff is currently reviewing its processes to identify near-term ways to improve efficiency and effectiveness in licensing, inspection, and enforcement. We expect to identify enhancements to the certification and licensing of storage casks, to the integration of inspection and licensing, and to our internal procedures and guidance. More information on the staff’s plans can be found in COMSECY-10-0007.

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## **The NRC is reviewing applications for new nuclear power plants. What is the environmental impact of all that extra fuel?**

Continued use and potential growth of nuclear power is expected to increase the amount of waste in storage. This increased amount of spent fuel affects the environmental impacts to be assessed by the NRC staff, such as the need for larger storage capacities. In the staff’s plan to develop an environmental impact statement for longer-term spent fuel storage, a preliminary scoping assumption is that nuclear power grows at a “medium” rate (as defined by the Department of Energy), in which nuclear power continues to supply about 20 percent of U.S. electricity production.

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## **Questions and Answers – Security**

### **What about security? How do you know terrorists won't use all of this waste against us?**

For spent fuel, as with reactors, the NRC sets security requirements and licensees are responsible for providing the protection. We constantly remain aware of the capabilities of potential adversaries and threats to facilities, material, and activities, and we focus on physically protecting and controlling spent

fuel to prevent sabotage, theft, and diversion. Some key features of these protection programs include intrusion detection, assessment of alarms, response to intrusions, and offsite assistance when necessary. Over the last 20 years, there have been no radiation releases that have affected the public. There have also been no known or suspected attempts to sabotage spent fuel casks or storage facilities. The NRC responded to the terrorist attacks on September 11, 2001, by promptly requiring security enhancements for spent fuel storage, both in spent fuel pools and dry casks.

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## Questions and Answers – Emergency Planning

### **What emergency plans are required for spent fuel storage facilities at nuclear power plants undergoing decommissioning or sites that have completed decommissioning?**

Decommissioning reactors continue to be subject to the NRC's emergency planning requirements. For some period of time after the licensee ceases reactor operations, offsite emergency planning will be maintained. This period of time depends on when the reactor was last critical as well as site-specific considerations. Offsite emergency planning may be eliminated when the fuel has been removed from the reactor and placed in the spent fuel pool, and sufficient time has elapsed, such that there are no longer any postulated accidents that would result in offsite dose consequences large enough to require offsite emergency planning. There would be no requirement to maintain offsite systems to warn the public. Onsite emergency plans will be required for both the spent fuel pool and the Independent Spent Fuel Storage Installations, but offsite plans will not be required. If, however, an operating plant is located at the same site as the decommissioning plant, the emergency preparedness plans will still be in effect for the operating plant.

Although offsite emergency planning at a decommissioned site may no longer be required, licensees maintain offsite contacts since any emergency declaration requires notification of state and local officials as well as the NRC. In addition, due to the typically reduced staffs at a decommissioning facility they may rely even more on offsite assistance for fire, security, medical or other emergencies. These reduced EP requirements would remain in effect as long as fuel is onsite.

*(Note: This general description also applies to emergency planning for specifically licensed ISFSIs; those requirements are spelled out in detail in 10 CFR 72.32.)*

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