U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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High Burnup Spent Fuel

Nuclear fuel is removed from a reactor every few years when it can no longer economically keep a chain reaction going. This “spent” fuel remains radioactive and must be managed. At first, it goes into a pool onsite for cooling and storage. Some utilities are moving their spent fuel after several years in the pool into NRC-certified dry storage casks. These casks are specially designed to contain the radioactivity and allow hot spent fuel to cool further.

What is burnup?

To understand “burnup,” it helps to know more about the uranium that fuels a reactor. Before it is made into fuel, uranium is processed to increase the concentration of atoms that can split in a controlled chain reaction in the reactor. The atoms release energy as they split. This energy produces the heat that is turned into electricity. In general, the higher the concentration of those atoms, the longer the fuel can sustain a chain reaction. And the longer the fuel remains in the reactor, the higher the burnup.

In other words, burnup is a way to measure how much uranium is burned in the reactor. It is the amount of energy produced by the uranium. Burnup is expressed in gigawatt-days per metric ton of uranium (GWd/MTU). Average burnup, around 35 GWd/MTU two decades ago, is over 45 GWd/MTU today. Utilities now are able to get more power out of their fuel before replacing it. This means they can operate longer between refueling outages. It also means they use less fuel.

Why does burnup matter?

The burnup level affects the fuel’s temperature, radioactivity and physical makeup. It is important to the NRC’s review of spent fuel cask designs because each system has limits on temperature and radioactivity. How hot and how radioactive spent fuel is depends on burnup, as well as the fuel’s initial makeup and conditions in the core. All these factors must be taken into account in designing and approving dry storage and transport systems for spent fuel.

Nuclear fuel is encased in metal cladding. In the reactor, this cladding reacts with cooling water. The reaction forms oxide on the outside (similar to rust) and releases hydrogen. These processes begin slowly, then start to accelerate as the fuel reaches burnup of 45 GWd/MTU. Anything higher is considered high burnup. But in reality there is no sharp line between low and high burnup. It is a continuum. That means the difference between fuel burned to 45 GWd/MTU and 46 or 47 GWd/MTU can be very small.

When spent fuel is placed in a dry storage system and the water is removed, the temperature of the fuel increases and the makeup of the cladding can change. This change can result in the fuel cladding becoming less “ductile,” or pliable, as it cools. It was also once thought that cladding of higher burnup fuel could become brittle enough to create a safety concern. Research now shows that while it may become less ductile, safety of the public will not be impacted for the systems the NRC has approved.

Is it safe to store and transport high burnup fuel?

To be certified by the NRC, dry cask designs must meet NRC requirements. For transportation, these are found in 10 CFR Part 71 and for storage in 10 CFR Part 72. The NRC approves designs only after a full safety review.

Based on these reviews, the NRC has certified cask designs for storage and transportation of high burnup spent fuel. Because low burnup spent fuel has been around longer and there is more of it, there are more casks for low than for high burnup spent fuel. There is also a great deal more data on low burnup fuel. Still, there is enough data on high burnup fuel that the NRC has certified high burnup spent fuel storage casks for an initial term of 20 or 40 years. Some systems have also been approved for transporting high burnup spent fuel. Operating experience since dry storage began in 1986 and short-term tests show both low and high burnup spent fuel can be stored and transported safely.

How does the NRC make sure it remains safe?

The NRC assures safety by requiring many layers of protection. Cask designs provide several layers and the fuel cladding itself provides added protection. The regulations are designed to ensure the health and safety of the public is maintained during storage or in a transportation accident. The NRC's regulations ensure the system will remain safe even if the cladding did break. The NRC carefully reviews each cask application to see if it meets the requirements. As part of this review, the NRC does its own analysis to confirm information in the application.

The NRC also provides oversight before and during loading of dry casks to ensure the correct fuel will go into the right storage systems. Fuel with burnup higher than the NRC certificate allows cannot be loaded. It must remain in pool storage until a cask approved for higher burnup becomes available. The NRC also inspects loaded casks every few years.

What confirmatory research is being done?

The primary focus of research today is to get more data to support the continued certification of storage systems beyond the initial 20- to 40-year license term. Additional research is ongoing to confirm that high burnup fuel will remain safe during transport after extended storage. This research is designed to ensure that the existing data on high burnup spent fuel is accurate and can be reproduced.

Cask designers are also involved in research that will assist them in designing casks for higher burnups and additional fuel types. As more data becomes available, the NRC expects to be able to certify more casks. Testing has provided a lot of information on how different types of cladding on spent fuel will behave, and this work continues.

The NRC is conducting tests at the Oak Ridge National Laboratory on high burnup fuel samples under stresses greater than the loads expected during normal transport. These tests have already shown that high burnup fuel is very strong. This information further confirms that long-term storage and eventual transportation of high burnup fuel is safe.

In addition, planning is underway for an important new study, run jointly by the nuclear industry and the Department of Energy, with regulatory oversight by the NRC. In this study, high burnup spent fuel will be loaded into a cask fitted with instruments to provide temperature readings and allow sampling of the gas inside. Those readings, combined with tests on the fuel assemblies and inspection of the cask's interior after years of dry storage, will provide more data. The test is expected to confirm the current understanding of what happens to high burnup spent fuel in a storage cask as it cools over time.

All this work will help cask designers, users and regulators better understand how to ensure high burnup spent fuel will remain safe in dry storage over the long term and during transportation to a centralized storage or disposal facility.

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