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IN PERSPECTIVE

The Downside of High Burnup Fuel

Robert Alvarez, of the Institute for Policy Studies, looks at the impact of high burnup fuel in the US as part of NIW's ongoing series on nuclear waste management.

Nuclear power plants are not just about generating electricity. They are now major radioactive waste management operations storing concentrations of artificial radioactivity that dwarf those generated by the US nuclear weapons program. Now that these wastes are likely to remain in storage at reactor sites for the indefinite future, there is one issue of particular concern -- high burnup nuclear fuel, which currently constitutes virtually all the fuel used by US utilities in power reactors. Questions recently raised by a Department of Energy (DOE) expert panel suggest that neither government regulators nor end-users understand the potential impact of irradiated high burnup fuel on storage and transport, or ultimately on nuclear waste management costs.

By increasing the percentage of uranium-235, the key fissionable material that generates energy, high burnup fuel allows reactor operators to effectively double the amount of time fuel is irradiated while reducing the frequency of costly refueling outages. This has been a major contributor to higher capacity factors in the US over the past couple of decades. Twenty years ago the average burnup for the US reactor fleet as measured by the amount of energy expressed in gigawatt days per metric ton of uranium was 35 GWd/MTU. Power reactor fuel burnups now routinely exceed the Nuclear Regulatory Commission (NRC) limit set for reactor operation for high burnup at 45 GWd/MTU. A growing amount of spent nuclear fuel has burnups higher than 55 GWd/MTU and reactor operators want it as high as 75 GWd/MTU.

While this trend may have improved the economics of nuclear power sales, the industry and its regulator have taken a questionable leap of faith that could, according to the Electric Power Research Institute, "result in severe economic penalties and in operational limitations to nuclear plant operators." Evidence is mounting that nuclear fuel cladding under high burnup conditions may not be relied upon as a primary barrier to prevent the escape of radioactivity, especially during prolonged dry storage. Resolution of these problems remains elusive. For instance:

- fuel cladding thickness is reduced to form a hydrogen-based rust of the zirconium metal which can cause the cladding to become brittle and fail;

- increased pressure between the pellets and the inner wall of the cladding causes the cladding to thin and elongate;

- high burnup fuel temperatures make it more vulnerable to damage from handling and transport; removal from the pool, vacuum drying and emplacement in canisters can result in cladding failure.

The NRC and the nuclear industry lack the predictive capabilities to address these problems. Erring on the side of caution might mean leaving high burnup fuel in pool storage for 25 years to allow cladding temperatures to drop enough to reduce risks of cladding failure before the fuel is transferred to dry storage. Meanwhile, reactors are maxing out their wet storage with more than 70% of the nation's 77,000 metric tons of spent fuel in reactor pools, of which roughly a fourth is high burnup. So far, about 8% of high burnup is sprinkled amidst lower burnup fuel in dry casks at reactor sites. By 2048 -- DOE's date for opening a geologic disposal site -- the amount of spent fuel could double, with high burnup accounting for as much as 60% of the inventory.

While the NRC's 2014 "continued storage" rule recognized the strong likelihood of long-term surface storage, it basically ignored high burnup spent fuel. This partly explains why the agency currently permits dry storage casks to accommodate a uniform loading of spent fuel below 45,000 MWd/MTU. A few high burnup assemblies, with higher decay heat, may be mixed in with lower burnup assemblies but there is little guidance on how this can be done without exceeding NRC peak temperature requirements.

The impacts of decay heat from high burnup spent fuel on the internal environment of commercial dry casks are virtually impossible to monitor "because of high temperatures, radiation, and accessibility difficulty," according to a 2014 NRC-sponsored study. Uncertainties are compounded by the lack of data on the long-term behavior of high burnup spent fuel. This problem was highlighted by the Nuclear Waste Technical Review Board, an expert panel that provides scientific oversight for the DOE on spent fuel disposal, which said there is little to no data to support dry storage and transport for spent fuel with burnups greater than 35 GWd/MTU. In a May 2016

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letter to the DOE, the board raised elemental questions about the issue. "What could go wrong? How likely is it? What are the consequences?"

Yet it will take the DOE at least a decade to complete a study involving temperature monitoring in a specially-designed single dry cask containing high burnup fuel. Meanwhile, as high burnup inventories increase, the higher amounts of radioactivity and decay heat are putting additional stress on pool storage systems. As a result, pool cooling systems are likely to require upgrading, which will certainly drive up costs at a time when age and deterioration of reactor spent fuel pool storage systems are of concern.

Finally, given the likelihood that spent nuclear fuel will have to be repackaged into smaller containers ahead of final disposal, high burnup fuel will only complicate the process, and increase costs. The basic approach undertaken in this country for storage and disposition of spent fuel needs to be fundamentally revamped. Instead of waiting for problems to arise, the NRC and the DOE need to develop a transparent and comprehensive road map identifying the key elements and especially the unknowns associated with the long-term storage, transportation, repackaging and ultimate disposal of all nuclear fuel, including high burnup. Otherwise, we will remain dependent on leaps of faith that are setting the stage for large, unfunded radioactive waste "balloon mortgage" payments.