Assurance of Nuclear Reactor Fuel Cooling and Integrity

The following provides a summary level comparison of the functional capabilities that must be fulfilled to ensure cooling of nuclear reactor fuel for typical commercial light water reactor designs and modular helium-cooled reactor designs. This cooling is required to ensure that fuel integrity is maintained. The source of heat in a nuclear reactor that must continue to be removed following reactor shutdown is from radioactive decay of nuclear fission byproducts ("decay heat"). The decay heat generation rate rapidly decreases over time, but continued heat removal is required.

Light Water Reactors (LWRs)

- Reactor shutdown is achieved through insertion of control rods (immediate) and is augmented through addition of liquid reactivity control (e.g., boron) to ensure continued shutdown as the reactor cools.
- Heat removal is achieved through circulation of the water inventory (coolant), or boiling off and venting. Such heat removal must be initiated within tens of minutes after shutting down the reactor. The water inventory must be maintained and the nuclear core must be kept covered with water or bathed in steam.
- Existing LWRs require active systems (e.g., pumps and valves) to control coolant inventory and heat removal.
- Advanced LWRs rely on passive systems (gravity driven) to control inventory and heat removal.
- Fuel integrity is maintained by controlling the temperature of the zirconium metal cladding (sheathing) on fuel rods to less than ~2200 oF.

Modular Helium-cooled Reactors (MHRs)

- Reactor shutdown is achieved through insertion of control rods (immediate). No additional shutdown action is required.
- Heat removal is achieved through conduction and radiation to the surrounding earth. No active systems or maintenance of the helium inventory is required. This heat removal capability is inherent to the design configuration and is always functional.
- Fuel integrity is maintained by controlling the temperature of the ceramic coating on fuel particles below ~3000 oF. The ceramic coated fuel will not degrade significantly for considerably higher temperatures.