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Nuclear power is expected to play a significant role in meeting future electricity needs, and in significantly reducing emissions compared to fossil-fueled power plants. However, the next generation of nuclear power plants will be expected to demonstrate significant advancements in economics, safety, waste disposal, and proliferation resistance. Many reactor types have been proposed for "Generation IV", some of which have been fast reactors. The work discussed in here is part of a larger effort at the Idaho National Engineering and Environmental Laboratory (INEEL) and at the Massachusetts Institute of Technology (MIT) to investigate the suitability of lead-bismuth cooled fast reactors for producing low-cost electricity as well as for actinide burning. The goal of the entire project is to identify and analyze the key technical issues in core neutronics, materials, thermal-hydraulics, fuels, and economics associated with the development of this reactor concept. The goal of the work presented in this paper is to investigate and compare a variety of possible fuel types, looking for optimum economics for an actinide burning, low cost of electricity, reactor design using sodium or lead-bismuth as the coolant.

While considerable design work has been done in the United States, Europe, and Japan on fast reactors, including actinide burners, most of the work has been done for sodium cooled reactors. The choice of coolant will affect the TRU destruction rate, the reactivity swing of the reactor, and the breeding ratio. The Russians adopted lead-bismuth coolant for use in their most advanced nuclear submarines, the so-called "Alpha" class submarines, which are the fastest in the world. The Russians have built and operated seven lead-bismuth-cooled reactors in submarines and two on-shore prototypes. More recently they have studied the design of a variety of lead and lead-bismuth cooled reactors for electric power generation, with the most recent using a fertile nitride fuel and lead coolant for the proposed BREST reactor.

However, there are other considerations in choosing the reactor coolant, such as material compatibility and limiting neutron fluences. Lead-bismuth can be corrosive to structural materials at the temperatures of interest, but the advantages of lead-bismuth over sodium as a coolant are related to the following material characteristics: chemical inertness of lead-bismuth with air and water; high atomic number; low absorption cross section; low vapor pressure; and a small volume change upon solidification. These basic properties lead to the following advantages for a lead-bismuth coolant:

- harder neutron spectrum and, therefore, improved neutron economy, especially when burning actinides;

- better reflective properties, making it is possible to get breeding even without blankets;
- better shielding against gamma-rays and energetic neutrons;
- high boiling temperature and high heat of vaporization of lead-bismuth (a boiling temperature of 1725C versus 892C for sodium), making it practically impossible to create a major void in the core due to coolant overheating;
- simpler containment structure due to the impossibility of fires and explosions; and
- a small volume change upon solidification.

On the other hand, sodium technology is well developed and has been proven. The Integral Fast Reactor (IFR) project is the most notable accomplishment, where the integrated fuel cycle reduces the TRU discharge significantly, and its safety performance was exceptional. Nevertheless, the main goal of the concept presented here is to maximize the TRU destruction rate while keeping the economic costs low, implying that the fuel remain in the reactor for relatively long periods. The choice of fuel also becomes an important issue in this type of system, as it will determine the core life, the amount of actinides burned, and the safety characteristics of the reactor.

One of the unique aspects of the work presented here is that it uses various different fuel forms; including the use of LWR plutonium and minor actinides as the fuel. The current work uses the MOCUP (MCNP-ORIGEN2.1 Coupled Utility Program) code to analyze the reactivity characteristics and isotopic concentrations of unit fuel pins/cells, with 38 actinides and 50 fission products being tracked. The fuels being studied are non-fertile metallic, fertile metallic, and fertile nitride fuels with the fertile material consisting of naturally occurring uranium or thorium. Previous work used different fuel types in a lead-bismuth-cooled reactor that had a constant pitch to diameter ratio, varying actinide loadings, and various power densities. The calculations show actinide burn rates that come within 15% of that calculated from the ATW. Also shown were derated, fertile fueled cores that had a lifetime ranging from 17 to more than 20 effective full power years. The focus of this paper is a comparison of these long-lived cores using sodium or lead-bismuth as the coolant; with a particular emphasis on the reactivity swing with burnup, and the end-of-life (EOL) isotopics.