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Inert matrix fuel deployment for reducing the plutonium stockpile in reactors

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Abstract – The 450 reactors operating (Nov. 2016) around the world (30 countries) produce about 100 tonnes of plutonium annually, in spent fuel. Some amounts are separated through reprocessing. While the recycling of plutonium as MOX fuel derives additional energy from this resource, it does little to address the issue of growing plutonium inventories. If a political objective is to reduce the amount of plutonium, then inert matrix fuel (IMF) provides an option for plutonium destruction. More generally, the utilization of plutonium in IMF provides flexibility in balancing the quantity of plutonium, by enabling the net burning of plutonium. This approach is viable in existing cores (Gen II&III) that already utilize MOX fuel. IMF can be used both to manage plutonium inventories and to contribute to reduce the long-term radiotoxicity of the spent fuel by minor actinide destruction. Some of these IMF materials are also being considered for Gen IV reactors, because of their advanced performance, economics, safety features, sustainability, and application to waste minimization in a closed fuel cycle.

Several promising candidate materials have been identified for both fast and thermal reactors: MgO (magnesia), ZrO2 (zirconia), SiC (silicon carbide), Zr (alloys), ZrN (zirconium nitride); some of these have undergone test irradiations and post irradiation examination. These materials may be used as cylindrical pellets, prismatic designed blocs, or as micro-spheres utilized as sphere-pac or kernels. They can be utilized at the fuel assembly level as prismatic (vertical or horizontal) set up such as in Light Water Reactors, Pressured Heavy Water Reactors or Liquid Metal Fast Reactor, or, as spherical such as in a High Temperature Gas-cooled Reactor. The fuel itself may be homogeneously composed of IMF or heterogeneously loaded with the IMF and uranium material. The assemblies may be homogeneously or heterogeneously loaded with the IMF, and the reactor core may be homogeneously or heterogeneously loaded with IMF assemblies. These three levels, i.e. fuel, assembly and core, of IMF utilization in LWR are considered within a homogeneous-heterogeneous concept scheme as recently reported in the IMF workshop. Modelling and testing IMF fuel performance and safety analysis have progressed. Fabrication methods have also been developed or adapted from existing technologies. System studies have identified strategies for both implementation of IMF fuel in existing reactors in the shorter term, as well as in new reactors in the longer term. Finally for the backend the burned IMF should be an attractive waste form to dispose or in specific conditions easy to reprocess.

The work to date has established the feasibility of these IMF materials, and core loadings and reactor strategies for utilizing these fuels. Further developments are required before commercial deployment of IMF, which will require additional resources. Additional in-pile irradiations have been suggested, both for normal operating and accident conditions. Further safety analysis and tests are required. Some development is needed for analysis tools and computer programs. Irradiations in commercial reactors should be undertaken in a staged approach as soon as possible: segmented rods, full-length rods, then lead assemblies. IMF can play an important role in the future of nuclear power.

Summary

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