Safe Fuels for Fast Spectrum Systems

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Fast spectrum reactors are the most likely systems to provide a true energy sustainability because they can breed fertile material and allow a high burn-up of the fissile material in the fuel. For the public acceptance of nuclear power it is equally important that they can extensively burn the higher actinides of the LWR waste – provided that an efficient reprocessing can be performed. For very safe fast critical reactors or Accelerator-driven systems (ADS) the type of coolant and fuel is highly important. Regarding the coolant, we believe that heavy metal coolants such as Pb/Bi are quite advantageous compared to sodium that it used in the current generation FRs because they do not react violently with water or air. Moreover, due to their high density and low vapor pressure these coolants can sweep molten fuel out of the core in case of overpower or undercooling accidents.

This “sweep-out” phenomenon depends to a large degree on the type of fuel. From a Russian submarine accident it can be assumed that molten oxide fuel pellets disintegrate and become suspended in liquid Pb/Bi in a coolable manner. This is partially due to the similar densities of oxide fuel and heavy metal coolant. Metal fuel partially dissolves in such a coolant but it is not clear how fast molten fuel would actually dissolve. If it clogged the coolant channels first, it would not be helpful. Nitride fuel dissociates below its melting point. It is uncertain whether this would lead to an explosive behavior of the pin (which may be admissible if it were not too strong) or just to cladding failures leading to a strong gas release. Since fast systems are not in their most critical configuration, re-criticalities are potentially possible. Therefore, the above mentioned aspects are important if we are aiming for a deterministically catastrophe-free fast spectrum reactor. Besides analytical efforts, out-of-pile and in-pile experiments are needed to investigate these phenomena.

The possible blow-out of fission gas plena in accidents in both critical and ADS systems is also of a certain concern because it may lead to a temporary voiding of the core. We could probably use a porous medium in the gas plena – which would be somewhat similar to the porous carbon buffer around coated particles of HTRs. Metal foams of up to 95% void fraction can be manufactured from high melting point metals such as nickel-chromium. These could probably be used for massively slowing down the gas release from ruptured pins.

In the full paper the materials aspects like dissolution of metal fuel and the nitride dissociation will be discussed in some detail. Different accident sequences will also be addressed and it will be shown where the above mentioned phenomena play a role. Furthermore, calculations on the sweep-out of oxide fuel by Pb/Bi coolant will be presented.