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Plutonium Diversion Effect on Molten-Salt Reactor Dynamics

Molten Salt Reactor (MSRs) are different from many other reactor designs in that they operate using liquid fuel. There are significant challenges concerning safeguards in liquid fuel systems. MSRs do not currently have any agreed upon method of safeguarding. Since MSRs are still in the design phase, there is ample opportunity to implement a Safeguards-by-Design (SBD) approach. Safeguard approaches for current reactors rely heavily on item accountancy, especially when the fissile material under consideration is highly radioactive. However, methods requiring material counting are impossible for the liquid fuel in MSRs. There are other reactor designs, such as those that use pebble fuel, where item accountancy is not applicable. Typical means of safeguarding these reactors consists of maintaining Continuity of Knowledge (CoK) of containment and surveillance. This method could be problematic in the long term, since, if there is a loss of CoK, then the reactor operators could be in violation of international safeguard agreements. As a result, there must be a means for in-core material accountancy. Another barrier to in-core material accountancy is the high temperature and the highly radioactive nature of the fuel salt. This makes in-vessel instrumentation difficult. For MSRs that operate on the U/Pu cycle, there will be a buildup of plutonium in the fuel with burnup. This buildup increases the fraction of fissions in the core resulting from plutonium rather than uranium, and thus the kinetic parameters will change throughout the burnup. As a result, the reactor dynamic response to reactivity perturbations such as a sinusoidal reactivity insertion will change in the event of plutonium diversion. This research investigates the dynamic response shift and attempts to link it back to the change in U-to-Pu fission ratio. This paper briefly details the characteristic changes in dynamics in the case of plutonium withdrawal and the effects that can be detected. In doing so, the hope is to help provide a methodology that could be implemented as part of an MSR SBD strategy.