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Development Potential for Thermal Reactors and their Fuel Cycles*

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Molten Salt Reactor(MSR) concepts offer the potential to contribute to the world's energy supply in the time frame of interest in this paper. Molten Salt Reactors come in a great variety with many options [1]. Only MSRs with on-line fuel processing and external cooling are considered in this paper. External cooling means that the fuel itself serves also as the coolant and is circulated from the critical core to a heat exchanger, which is external to the core. Only fluoride salts are considered as they are subject to the fluoride volatility process [2], which readily permits separation of the uranium from the salt. Molten Salt Reactors are unique in that they do not have a fuel cycle in the usual sense. Also, MSRs have extraordinary safety features [3], which derive primarily from their on-line processing, and the fact that the fuel is a fluid. Fuel expansion upon heating pushes the fuel out from the core resulting in a strong negative reactivity temperature coefficient, which provides control. The concept of a "meltdown" accident is meaningless for MSRs.

On-line continuous processing results in an equilibrium fuel that requires only a very little "excess" reactivity to compensate for control or "burn up," and hence there is no driving force for a reactivity excursion accident. Also, the radioactive source-term of MSRs can be made quite small via on-line fuel processing [4].

The "fuel cycle" of solid-fuel reactors is replaced in MSRs by a continuous equilibrium state. Criticality is maintained by continuous removal of fission products and the addition of fissile material for a converter or the removal of fissile material for a breeder. The only remaining portions of a "cycle" are the initial start up of a reactor with fresh fuel and, at the end-of-life of the reactor, the remaining fuel. However, even these insignificant residues of a fuel cycle are rendered meaningless if the reactor is started up with fuel from a previous reactor and the end-of-life fuel is transferred to the next reactor. Thus, there is no meaning to "burnup" in MSRs. A particular "batch" of fissile material can be burned completely (100% burnup) simply by leaving it in the reactor until it is consumed. This is significant when one type of fissile material, such as plutonium, is used. Plutonium can be burned completely, and its last "residue" is replaced by another type of fissile material such as uranium [5].

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MSRs can be used to completely dispose of plutonium while utilizing the plutonium for energy generation. This property of total utilization of the fissile material, coupled with the high efficiency of MSRs, and also the ability to thrive on Th-U fuel results in optimal long-term resource utilization with little environmental impact.

At the time MSRs were first studied, in the 50s and 60s, the primary emphasis was on high breeding and short doubling time. The terminology "fuel cycle" referred to the synergism of various reactor systems, rather than to the fuel management of a single reactor. The emphasis on breeding performance [6] is not expected to regain its past importance in the near future. There is now more room to develop and emphasize the non-proliferation and waste-simplification aspects of the MSRs. The ability to dispose of Pu and HEU have already been mentioned. The utilization of Th-U-233 fuel also has non-proliferation advantages. The U-233 is protected by the high-energy gamma radiation of the daughter products of U-232 which accompanies the U-233. The fluid nature of the fuel and its relatively high melting point require elaborate and sophisticated means for handling and manipulation, which makes diversion and subsequent proliferation extremely difficult.

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