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The Case for Integrating Nuclear Material /Waste Management into Reactor Development for the Modular Helium-Cooled Reactor (MHR)

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The demonstrated MHR fuel capability to consume weapon-grade Plutonium (w-Pu) to better than 90% (>700,000 MWD/ton burnup, more than 10 times the burnup possible in LWRs) forms the basis for the inclusion of the MHR in the DOE-NNSA program to destroy w-Pu. Transuranics extracted from LWR spent fuel (a mixture of Plutonium, Neptunium, Americium and Curium) can also be destroyed to a similar extent in the MHR, providing a natural GNEP (Global Nuclear Energy Partnership) role for the MHR together with the fast spectrum Advanced Burner Reactor (ABR).

The MHR high-burnup disposition concept (Deep Burn) has been proposed by General Atomics and positively evaluated by National Laboratories and academic researchers for destruction of w-Pu and the transuranic waste from LWRs, as recently proposed in a GNEP expression of interest (EOI). The appropriate MHR core and fuel designs are expected to be substantially identical and easily testable in the reactor considered by DOE for construction at the Idaho National Laboratory site (NGNP).

Furthermore, General Atomics' recent economic analysis indicates that, due to the extremely large burnup that can be achieved in MHRs with fully enriched Pu and TRU fuels, the operation of these reactors in a w-Pu or TRU deep-burn destruction mode will not result in economic penalties, and that substantial savings can be expected over the use of Plutonium MOX in LWRs. It only stands to reason that the highest energetic (and economic) return for nuclear material destruction will be obtained by the system that provides the most complete and efficient utilization (burnup) of the material. The near-full utilization of fuel in Deep-Burn MHR operations opens entirely new possibilities with respect to the economics of fuel recycle and material disposition.

This is an extremely important conclusion because it indicates that extensive commercial deployment of MHRs will benefit, not hinder, the fuel recycle objectivesof GNEP. It is for this reason that the demonstration of high burnup disposition capabilities of the MHR should be fully integrated into the NGNP development. The relevant main development and demonstration activities would be associated with Plutonium and Transuranic TRISO fuel and its reprocessing for recycle.

MHRs enable a rapid expansion of total nuclear energy generation by filling market segments that LWRs and Fast Reactors cannot service effectively, complying to GNEPs directives for world-wide deployment, and by uniquely providing an economic attractiveness for the mission of LWR TRU and w-Pu destruction:

- MHRs have attractive economics and improved utilization of uranium due to high efficiency for electricity production (approaching 50%, to be compared to the ~33-35% typical for electricity generation in lower temperature LWRs), and capability to fill key market segments where LWRs are not competitive (electricity production with dry cooling or thermal desalination in areas with water scarcity like the U.S. Southwest, direct production of hydrogen and process heat for transport and petrochemical applications, and deployment to small grids in developing countries).
- Deep-Burn recycle of TRU and Plutonium in MHRs, (effective destruction to 700,000 MWD/ton), produces a waste form that is free of weapons-usable material, with substantial destruction of heat-generating actinides and suitable for further destruction in Fast Spectrum reactors.
- Diverse materials (uranium, thorium, plutonium, TRU) can be used as fuel within the same MHR design.
- MHR's trademark inherently safe operation and modular small-footprint design for maximum flexibility of deployment domestically and abroad.
- Economics for high burn-up operations (using w-Pu or transuranics) are attractive compared to the use of conventional LEU fuel.

It is a major advantage that the MHR technology, introduced with NGNP as a major new reactor system for commercial application, is also suited to contribute to the disposition/recycling mission and capable of destroying the heat generating actinides that limit repository capacity. MHRs are uniquely attractive for this reason, because they will require no subsidies to compete with LWRs (particularly in the large energy market segments where LWRs currently cannot penetrate at all) beyond support for first-of-a-kind engineering and commercialization costs.

The key to the MHR behavior and performance with respect to TRU and Plutonium destruction lies in its TRISO fuel. This engineered fuel form (micro-fuel) is made of small particles having a 200-400 micron heavy-metal core surrounded by carbon and silicon carbide structural layers that can contain the fuel and fission products under all normal and off-normal reactor events, thus giving rise to the "inherently safe" character of the reactor concept.

Although TRISO fuel is not being fabricated in the US at present in commercial amounts, there is a considerable and demonstrated experience base for large-scale fabrication of high quality TRISO fuel both in and outside the US, and there is work to re-establish this U.S. capability being carried out at ORNL and elsewhere. TRISO fuel can be designed for standard LEU operations (large kernels) and for deep-burn destruction operations (small kernels), both can be fabricated using similar techniques and apparatus. The extension of the LEU-based fuel fabrication experience to the manufacturing of w-Pu-based fuel is currently a major focus of U.S.-Russian collaboration under the NNSA project, and is based upon successful experience in fabricating and irradiating Pu TRISO fuel 30 years ago in the Peach Bottom I plant, see Fig. 1.

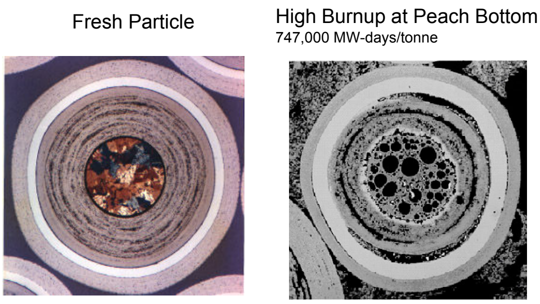

Fig.1 Example of high-burn-up plutonium fuel from Peach Bottom I

This U.S.-Russian collaboration is being pursued in a proof-of-principle bench-scale facility, first with uranium surrogate and ultimately plutonium fuel.

Manufacturing of Pu and TRU TRISO will require the implementation of remote handling techniques and the development fuel designs specifically geared to very high burn up. Plutonium fuel design and fabrication techniques developed for the NNSA program will be fully applicable to the Spent Nuclear Fuel Transuranic burning mission of GNEP. A first step could be extending the bench scale facility to develop deep burn TRISO fuel and to work with Russian fuel specialists in remote handling techniques for implementation of TRU TRISO fabrication in the Russian facility.

TRISO fuel can also easily be integrated into GNEP recycling. To that effect, the simple addition of a TRISO "head-end" such as METROX or "Grind and Leach" to the main GNEP partitioning schemes (UREX+ or PYRO) is all that would be required. Spent TRISO fuel, be it from LEU, w-PU or LWR-TRU fuels, can be further recycled in fast reactors (Fig.2) with favorable safety features and economics advantages over the direct disposition of these materials in the fast reactors, as proposed in the original GNEP outline.

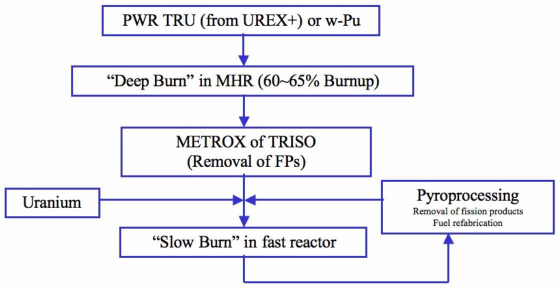

Fig.2 The synergy between MHRs and fast reactors optimizes the roles of both, resulting in the smallest waste stream, the largest power from disposition of waste or special nuclear material, at the lowest cost.

REFERENCES

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