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DEVELOPMENT OF A RECYCLE FUEL FOR THE HTGR*

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SUMMARY

Early development work on fissile particles for HTGR recycle application was done with UO_2 kernels. This system was abandoned when irradiation testing revealed a severe problem of thermal migration (amoeba) of the kernels through the coating layers. Thoria-containing fertile particles showed good resistance to amoeba, which suggested diluting the fissile kernels with ThO_2. Migration rates for this system were also unacceptably high, and a new fissile kernel was sought.

Development of resin-based fuel for coated particle application has been under way for several years. Studies have included several ion exchange resins, various uranium loading schemes, carbonization cycles, control of conversion (reduction) to carbide, handling, coating, and irradiation testing.[1—5] Preliminary economic assessment indicates that resin fuel is no more expensive to fabricate than dense kernels and may be economically superior. In addition, this system has considerable flexibility in stoichiometry, kernel density, and uranium loading. A Weak-Acid Resin-derived (WAR) kernel has been selected as the new reference recycle fuel, and the irradiation program reoriented toward establishing optimum specifications. The loaded resin is carbonized to a dispersion of UO_2 in carbon at about 1200°C. Continued heating to higher temperatures can convert the UO_2 to carbide, completely at 1800°C.

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The irradiation performance of partially converted WAR kernels has been shown superior to that of UO_2 or mixed-oxide kernels. Examination of 0%-converted WAR kernels (UO_2 plus carbon) reveals performance very much like that of dense UO_2 kernels. Conversely, 100%-converted WAR performs very much like dense UC_2, where performance is limited by rejection of the high-yield rare-earth fission products La, Pr, Ce, and Nd. Partially converted kernels do not amoeba, and the presence of oxygen results in the formation of rare-earth oxides, which are retained within the kernel.

Performance of WAR fuels at three levels of conversion is compared in Fig. 1. The migration of the 0%-converted particle is shown on the left. The coating failure shown in the 100%-converted particle (on the right) is a result of either chemical attack of the SiC layer by the rare-earth fission products or mechanical failure caused by the accumulation of rare-earth fission products at the inner surface of the SiC layer. The 50%-converted particle in the center shows no amoeba and no attack of the SiC layer. Our experiments to date show acceptable performance over a conversion range of 15 to 75%, although the 15%-converted fuel appears to have operated molten under accelerated irradiation conditions. The consequences of this under real-time testing remain to be verified.

We are confident that the WAR system will perform satisfactorily under reference HTGR conditions, and our testing program is now oriented toward developing product specifications and establishing the limits of performance.

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FIGURE CAPTION

Fig. 1. Performance of Triso-Coated Weak-Acid Resin Kernels Irradiated in HRB-10. Burnup: 80% FIMA — Fast Fluence 4.8–5.0 × 10^{21} n/cm^{-2} (E > 0.18 MeV). Design center line temperature: 1500°C.

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