Modelling Silver Transport

in

Spherical HTR Fuel

by

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Abstract

For direct cycle gas cooled high temperature reactor designs, operating conditions may be limited as a result of excessive maintenance dose rates caused by the ^{110m}Ag source term on the turbine. The accurate prediction of silver fission and activation products' release during normal operation is required to ensure regulatory compliance and economic viability of planned power plants. Fuel qualification programs should provide satisfactory results to ensure correct analyses, but will however not be available for many years. In the meantime data from the German fuel development program may be utilized. Traditionally diffusion models were used to derive transport parameters from limited irradiation testing of fuel materials and components. Best estimates for all applicable German fuel irradiation tests with defendable uncertainty ranges were never derived. However, diffusion theory and current parameters cannot account for all irradiation and heat-up test results, and for some tests, it appears unacceptably conservative. Other transport mechanisms have been suggested and alternative calculation models are being considered. In this thesis the relevant German material and irradiation tests were evaluated with the current PBMR metallic fission product release calculation model. Transport through all the fuel materials and components and from the sphere to the coolant gas was considered and best possible models and parameters were suggested. For the transport of silver through the SiC layer an alternative suggested model called the Molecular Vapour Transport Release (MVR) Model was evaluated against the traditional diffusion model. From this evaluation it was shown that classical diffusion modelling was still a viable model to predict silver transport in SiC. The MVR model was found to be a feasible model as well. However, due to the much larger verification and validation effort required, it was decided to use the diffusion model until such time that experimental results become available that might elucidate the exact physical transport model. The evaluation also showed that the diffusion model used must be quantified in a detailed evaluation of all applicable irradiation tests. A study of all German irradiation tests was previously performed and the applicable irradiation tests were identified. A detailed evaluation of these irradiation tests were performed with an updated diffusion model. New transport and material parameters were derived in this detailed evaluation and compared with existing values. An evaluation of some heat-up tests of irradiated fuel spheres was performed to assess the range for which the newly derived transport parameters are valid. The different models with their old and newly derived parameters were used to analyse sample PBMR cores. Recommendations were made to the suitability of the different models and parameters for future PBMR silver fission and activation product analyses.

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List of Acronyms and Terms

This list contains the abbreviations used in this document.

Abbreviation or Acronym	Definition
atm	atmosphere
AVR	Arbeitsgemeinschaft Versuchsreaktor
CP	Coated Particle
CVD	Chemical Vapour Deposition
DLOFC	Depressurized Loss of Forced Cooling
EFPD	Equivalent Full-power Days
FE	Fuel Element
FIMA	Fissions per Initial Metal Atoms
FIPREX	Fission Products Release under Extraordinary conditions
FZJ	Forschungszentrum Jülich GmbH
GA	General Atomics
GETTER	Software used to model fission product transport in spherical fuel
HBK	Hochtemperaturreaktor-Brennstoff-Kreislauf
HEU	Highly Enriched Uranium
HFR	High Flux Reactor
HRB	Hochtemperatur Reaktorbau
HTA	Hochtemperatur Anlage
HTR	High Temperature Reactor
HTR-Modul	High Temperature Reactor - Modular design
IAEA	International Atomic Energy Agency

Abbreviation or Acronym	Definition
IMGA	Irradiated Microsphere Gamma Analyzer
J	joule
K	kelvin
KFA	Kernforschungsanlage (Jülich)
KORA	Corrosion Apparatus
KÜFA	Cold finger apparatus
LEU	Low-enriched Uranium
LOFC	Loss of Forced Coolant
MCNP	Monte Carlo N-particle Transport Code
MPS	Main Power System
MVR	Molecular Vapour Transport Release
n/a	not applicable
NEA	Nuclear Engineering Analysis
NGNP	Next Generation Nuclear Plant
NTF	Nano-tube Failure
PBMR	Pebble Bed Modular Reactor
Pa	pascal
PIE	Post-irradiation Examination
ppm	parts per million
PyC	Pyrolytic Carbon or Pyrocarbon
R/B	Release-to-Birth
RDFM	Reactor Design and Fuel Management
SI	International System of Units
SiC	Silicon Carbide

Abbreviation or Acronym	Definition
SPN	Self-powered Neutron (detector)
TPD	Temperature Programmed Desorption
TRISO	Triple Coated Isotropic
V&V	Verification and Validation
VSOP	Very Superior Old Program

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