

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 defensible 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.

Table of Contents

Abstract.....	1
Table of Contents	2
List of Figures.....	5
List of Tables	6
List of Acronyms and Terms	8
Acknowledgements	11
1. Introduction.....	12
1.1 Fuel Design.....	13
1.2 Silver Fission and Activation Products	16
1.3 Fission Production Sources	17
1.3.1 Uranium and thorium contamination of the fuel materials.....	17
1.3.2 Defective and failed coated particles	18
1.3.3 Intact TRISO coated particles.....	19
1.3.4 Natural contamination of activation product precursors.....	19
2. Modelling Options.....	20
2.1 Diffusion Calculation Model	20
2.1.1 Fission product recoil.....	20
2.1.2 Diffusion	21
2.1.3 Surface sorption and mass transfer	21
2.2 Molecular Vapour Transport Release Calculation Model	24
3. Evaluation of Material Tests.....	26
3.1 Sorption Isotherms.....	26
3.2 Matrix Material Transport	31
3.3 Coated Particle Transport	33
3.4 Material Test Evaluation Discussion	35
4. Evaluation of Irradiation tests.....	36
4.1 Selection of Irradiation Tests.....	36
4.1.1 Fuel type.....	36

4.1.2	Irradiation history.....	36
4.1.3	Fractional release data.....	37
4.2	Molecular Vapour Transport Release Model	41
4.3	Diffusion Model	43
4.3.1	First estimate evaluation	43
5.	Detailed Evaluation.....	48
5.1	HFR-K3	48
5.1.1	Reactor	48
5.1.2	Irradiation test	49
5.1.3	Evaluation	52
5.2	FRJ2-K13.....	63
5.2.1	Reactor	63
5.2.2	Irradiation test.....	63
5.2.3	Evaluation	65
5.3	FRJ2-K15.....	69
5.3.1	Irradiation test.....	69
5.3.2	Evaluation	70
5.4	R2-K12	75
5.4.1	Reactor	75
5.4.2	Irradiation test.....	75
5.4.3	Evaluation	78
5.5	R2-K13	83
5.5.1	Irradiation test.....	83
5.5.2	Evaluation	84
5.6	FRJ2-K11.....	89
5.6.1	Irradiation test.....	89
5.6.2	Evaluation	90
5.7	Discussion of results.....	92
6.	Evaluation of Post irradiation Heat-up Tests.....	96
6.1	The KÜFA Instrument.....	96
6.2	Heat-up Tests	97
6.2.1	HFR-K3.....	98

6.2.2	FRJ2-K13	100
6.2.3	AVR 74/11	101
6.2.4	AVR 71/22	102
6.2.5	AVR 82/9	104
6.2.6	AVR 90/5	105
6.3	Discussion of Heat-up Tests	106
7.	Application in PBMR Core Analyses	107
7.1	PBMR Core Model and Analyses	107
7.2	Silver Release from a PBMR Core	109
7.3	Effect on PBMR Core Analyses Discussion	111
8.	Conclusions	113
9.	Recommendations	115
10.	References	117

List of Figures

Figure 1: Fuel Element Design	14
Figure 2: Thermal Neutron Fission Product Yields for ^{235}U	16
Figure 3: Experimental Desorption Spectra of Caesium (left) and Silver (right).....	27
Figure 4: Cs sorption: Experimental vs. GETTER Sorption Isotherm	28
Figure 5: Ag Sorption: Experimental vs. GETTER Sorption Isotherm.....	29
Figure 6: Old and New Ag Sorption Isotherms on A3-3 Matrix Graphite	30
Figure 7: Silver Diffusion Coefficient in the Matrix Material.....	32
Figure 8: Fractional Release of Fission Products after Irradiation	38
Figure 9: Fractional $^{110\text{m}}\text{Ag}$ Release: Experiment vs. MVR vs. Diffusion	43
Figure 10: Fractional $^{110\text{m}}\text{Ag}$ Release after Irradiation	44
Figure 11: Fitted IAEA, and First Estimate Best Estimate and Design Limit Curves.....	46
Figure 12: IAEA and First Estimate Best and Design SiC Diffusion Coefficients	47
Figure 13: HFR-K3: Flux Detector and Thermocouple Placement	50
Figure 14: FRJ2-K13: Irradiation Rig.....	64
Figure 15: FRJ2-K15: Irradiation Rig.....	71
Figure 16: R2-K12: Irradiation Rig for Spherical Fuel Elements.....	77
Figure 17: Diffusion Coefficients from the Detailed Evaluation.....	95
Figure 18: KÜFA-instrument used for Heat-up Testing [49]	97
Figure 19: Silver Release during Heat-up of HFR-K3/1	99
Figure 20: Silver Release during Heat-up of HFR-K3/3	99
Figure 21: Silver Release during Heat-up of FRJ2-K13/2.....	100
Figure 22: Silver Release during Heat-up of FRJ2-K13/4.....	101
Figure 23: Silver Release during Heat-up of AVR 74/11.....	102
Figure 24: Silver Release during Heat-up of AVR 71/22.....	103
Figure 25: Silver Release during Isothermal Heating of AVR 82/9	104
Figure 26: Silver Release LOFC Simulation of AVR 90/5	105
Figure 27: Sample PBMR VSOP Calculation Model Layout	108
Figure 28: Comparison of the Three Considered Diffusion Coefficients.....	112

List of Tables

Table 1: Considered Irradiation Tests.....	39
Table 2: MVR (NTF) and Diffusion Evaluation.....	42
Table 3: HFR-K3 Test Element Specification and Irradiation Data.....	51
Table 4: HFR-K3: Cycle Averaged Temperature Data	53
Table 5: HFR-K3: Thermal and Fast Neutron Fluxes ($\times 10^{18} \text{ m}^{-2}\text{s}^{-1}$).....	54
Table 6: HFR-K3: Gamma Heating (W)	55
Table 7: HFR-K3/1: Fission Power (W), Surface and Centre Temperatures ($^{\circ}\text{C}$).....	57
Table 8: HFR-K3/2: Fission Power (W), Surface and Centre Temperatures ($^{\circ}\text{C}$).....	58
Table 9: HFR-K3/3: Fission Power (W), Surface and Centre Temperatures ($^{\circ}\text{C}$).....	59
Table 10: HFR-K3/4: Fission Power (W), Surface and Centre Temperatures ($^{\circ}\text{C}$).....	60
Table 11: Fractional $^{110\text{m}}\text{Ag}$ Release from Fuel Elements of HFR-K3 [25].....	61
Table 12: Derived Diffusion Coefficients: HFR-K3	62
Table 13: FRJ2-K13/1 and /2: Fission Power, Surface and Centre Temperatures	66
Table 14: FRJ2-K13/3 and /4: Fission Power, Surface and Centre Temperatures	67
Table 15: Fractional $^{110\text{m}}\text{Ag}$ Release from Fuel Elements of FRJ2-K13 [25]	68
Table 16: Derived Diffusion Coefficients: FRJ2-K13.....	69
Table 17: FRJ2-K15 Test Element Specification and Irradiation Data	70
Table 18: FRJ2-K15/1 and /2: Fission Power, Surface, and Centre Temperature.....	72
Table 19: Fractional $^{110\text{m}}\text{Ag}$ Release from Fuel Elements of FRJ2-K15 [38]	74
Table 20: Derived Diffusion Coefficients: FRJ2-K15.....	74
Table 21: R2-K12 Test Element Specification and Irradiation Data	76
Table 22: R2-K12: Surface Temperature ($^{\circ}\text{C}$) and Neutron Flux ($10^{18} \text{ m}^{-2}\text{s}^{-1}$).....	79
Table 23: R2-K12: Fission and Gamma Power (W).....	80
Table 24: R2-K12: Calculated Centre Temperatures.....	81
Table 25: Fractional $^{110\text{m}}\text{Ag}$ Release from the Fuel Elements of R2-K12 [39].....	82
Table 26: Derived Diffusion Coefficients: R2-K12.....	82
Table 27: R2-K13 Test Element Specification and Irradiation Data	84
Table 28: R2-K13: Surface Temperature ($^{\circ}\text{C}$) and Neutron Flux ($10^{18} \text{ m}^{-2}\text{s}^{-1}$).....	85
Table 29: R2-K13: Fission and Gamma Power (W) and Centre Temperatures ($^{\circ}\text{C}$).....	87
Table 30: Fractional $^{110\text{m}}\text{Ag}$ Release from Fuel Elements of R2-K13 [25].....	89
Table 31: Derived Diffusion Coefficients: R2-K13.....	89
Table 32: FRJ2-K11 Test Element Specification and Irradiation Data	90
Table 33: FRJ2-K11/3 and /4: Fission Power, Surface and Centre Temperatures	91

Table 34: Derived Diffusion Coefficients: FRJ2-K11	92
Table 35: Summary of Derived Diffusion Coefficients.....	94
Table 36: Comparison of Calculated ^{110m}Ag Releases from a 400 MW PBMR Core.....	110
Table 37: Comparison of Calculated ^{110m}Ag Releases from a 300 MW PBMR Core.....	110
Table 38: Comparison of Calculated ^{110m}Ag Releases from a 500 MW PBMR Core.....	110

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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