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OPERATING HISTORY REPORT FOR THE PEACH BOTTOM HTGR

VOLUME II TEST ELEMENT OPERATING HISTORY

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ABSTRACT

Volume II of the Operating History Report for the Peach Bottom HTGR constitutes an overview of the Peach Bottom test element program and a detailed record of the fission gas release data determined for the various test elements. The report was prepared under the Peach Bottom End-of-Life Program which is jointly sponsored by ERDA and EPRI to validate specific HTGR design codes and predictions by comparison of actual to predicted thermal, physics, fission product, and materials behavior in Peach Bottom.

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1. INTRODUCTION

The Peach Bottom Unit 1 reactor offered unique capabilities as a fuel test facility for HTGR fuels. This was the only reactor in the United States which could irradiate HTGR fuel in a representative HTGR neutron spectrum and in a helium coolant environment. In addition, it could accommodate kilogram quantities of test fuels for long irradiation periods, and full-scale fuel element assemblies could be tested to evaluate the interactions of fuel particles, fuel beds, and graphite structures. One of the fundamental objectives of the second Peach Bottom Unit 1 core (Core 2), therefore, was to utilize the unique capabilities of this reactor as a test facility for irradiation of HTGR fuel concepts.

In the following sections an overview of the test element program is presented, together with a detailed record of the fission gas release data determined for the various test elements.

2. REVIEW OF TEST ELEMENT PROGRAM

The fuel test program consisted of three classes of test elements: fuel test elements (FTEs), proof test elements (PTEs), and fuel pin test elements (FPTEs).

A total of 33 test elements were constructed. Of these 33 elements, one was of the PTE design, two of the FPTE design, and 30 of the FTE design. Of the 30 in the FTE design, three contained fuel which was to be evaluated for the Fort St. Vrain reactor, seven contained recycle fuel for process demonstration tests at ORNL, one contained plutonium fuel in connection with an HTGR plutonium test program performed jointly between the Electric Power Research Institute (EPRI) and GA, one contained special fuel bodies manufactured by NUKEM, GmbH, of West Germany for a KFA-HOBEG-GA test program, and eighteen contained fuel being tested for the 3000/2000-MW(t) large HTGR.

Table 1 lists the most important parameters for each of the 33 test elements. The irradiation schedule for each element is shown in Fig. 1. Figure 1 shows the core position of each test element and also indicates which of the test elements were placed in individual purge positions. These are locations where the purge gas, which flows within the low-permeability graphite sleeve and over the test element fuel bodies, can be sampled and the fuel thereby monitored for fission gas release for that particular test element.

TABLE 1
PHASE 1, 2, AND 3 PEACH BOTTOM TEST ELEMENTS

Type	Phase ^(a)	Ident. Number	Core Position ^(b)	Thermo-Couples	Purge Sampling ^(c)	Fuel Bed	Fuel Particles	
							Fissile	Fertile
Fuel Test Elements								
Fuel bed test ↓	1	FBTE-1	C05-04	Yes	No	Rods ^(d)	(Th,U)C ₂ BISO	ThC ₂ BISO
	1	FBTE-2	A11-11	Yes	No	Rods	UC ₂ BISO	ThC ₂ BISO
	1	FBTE-3	B14-08	Yes	Yes	Rods	UC ₂ TRISO	ThC ₂ BISO
	1	FBTE-4	F06-01 ^(e)	Yes	Yes	Rods	(Th,U)C ₂ TRISO	ThC ₂ TRISO
	1	FBTE-5	D09-04	No	No	Blended ^(f)	(Th,U)C ₂ BISO	ThC ₂ BISO
							(Th,U)C ₂ TRISO	ThC ₂ BISO
	1	FBTE-6	F14-08 ^(e)	Yes	Yes	Blended	UC ₂ TRISO (Th,U)C ₂ BISO	ThC ₂ BISO
Fuel test ↓	1	FTE-1	A14-08 ^(e)	Yes	No	Blended	(Th,U)C ₂ BISO (Th,U)C ₂ TRISO UC ₂ BISO UC ₂ BISO	ThC ₂ BISO ThC ₂ TRISO
	1	FTE-2	A11-11 ^(g)	Yes	No	Blended	(Th,U)C ₂ BISO (Th,U)C ₂ TRISO UC ₂ BISO	ThC ₂ BISO ThC ₂ TRISO
	2	FTE-3	A03-03 ^(g)	Yes	No	Rods	(Th,U)C ₂ TRISO UC ₂ TRISO UO ₂ TRISO (Th,U)C ₂ TRISO	ThC ₂ BISO ThC ₂ BISO ThO ₂ BISO ThC ₂ TRISO

TABLE 1 (Continued)

Type	Phase (a)	Ident. Number	Core Position(b)	Thermo-Couples	Purge Sampling (c)	Fuel Bed	Fuel Particles	
							Fissile	Fertile
Fuel Test Elements								
Fuel test ↓	1	FTE-5	C14-08	Yes	No	Rods	UC ₂ BISO (Th,U)C ₂ BISO UC ₂ TRISO (Th,U)C ₂ TRISO	ThC ₂ BISO ThC ₂ BISO ThC ₂ BISO ThC ₂ TRISO
	2	FTE-6	C02-01	Yes	No	Rods	UC ₂ TRISO UO ₂ TRISO (Th,U)C ₂ TRISO (Th,U)C ₂ TRISO	ThC ₂ BISO ThO ₂ BISO ThC ₂ TRISO ThC ₂ TRISO
	2	FTE-7	F14-08	Yes	Yes	Rods	UO ₂ TRISO	ThO ₂ BISO
	2	FTE-8	D14-08	Yes	Yes	Rods	UC ₂ TRISO	ThC ₂ BISO
	2	FTE-9	D06-01	Yes	Yes	Rods	(Th,U)C ₂ TRISO	ThC ₂ BISO
	2	FTE-12	B06-01	Yes	Yes	Rods	(Th,U)O ₂ BISO	ThO ₂ BISO
	3	FTE-14	B03-02 ^(e)	Yes	No	Rods	UO ₂ TRISO UC ₂ TRISO UO ₂ TRISO UC ₂ TRISO (Th,U)O ₂ TRISO UO ₂ TRISO UO ₂ TRISO	ThO ₂ TRISO ThC ₂ BISO ThO ₂ BISO ThC ₂ TRISO ThC ₂ BISO ThC ₂ BISO ThC ₂ TRISO

TABLE 1 (Continued)

Type	Phase (a)	Ident. Number	Core Position (b)	Thermo-Couples	Purge Sampling (c)	Fuel Bed	Fuel Particles	
							Fissile	Fertile
Fuel Test Elements								
Fuel test ↓	3	FTE-15	A14-08	Yes	No	Rods	UO ₂ TRISO UC ₂ TRISO UO ₂ TRISO UC ₂ TRISO (Th,U)O ₂ TRISO UO ₂ TRISO UO ₂ TRISO	ThO ₂ TRISO ThC ₂ BISO ThO ₂ BISO ThC ₂ TRISO ThC ₂ BISO ThC ₂ BISO ThC ₂ TRISO
Plutonium fuel test ↓	3	FTE-13	E10-01	Yes	No	Rods	PuO ₂ TRISO (Th,Pu)O ₂ TRISO (Th,U)C ₂ TRISO	ThO ₂ BISO ThO ₂ BISO ThC ₂ TRISO
FSV proof test (FTE type) ↓	2	FTE-10 (PTE-3)	E02-01	Yes	Yes	Rods	(Th,U)C ₂ TRISO	ThC ₂ TRISO
	3	FTE-16 (PTE-4)	F06-01	Yes	Yes	Rods	(Th,U)C ₂ TRISO	ThC ₂ TRISO
	3	FTE-17 (PTE-5)	A02-01	Yes	Yes	Rods	(Th,U)C ₂ TRISO	ThC ₂ TRISO

TABLE 1 (Continued)

Type	Phase ^(a)	Ident. Number	Core Position ^(b)	Thermo- Couples	Purge Sampling ^(c)	Fuel Bed	Fuel Particles							
							Fissile	Fertile						
Fuel Test Elements														
Monolithic fuel test	3	FTE-18	E06-01	Yes	No	Monolithic	(Th,U)O ₂ BISO	None						
Recycle test ↓	2	FTE-11 (RTE-1)	E10-06	No	No	Rods	UO ₂ TRISO	ThO ₂ BISO						
							(Th,U)O ₂ BISO	ThC ₂ BISO						
							UC ₂ BISO	ThC ₂ BISO						
							UC ₂ TRISO	ThC ₂ TRISO						
							UC ₂ BISO	ThO ₂ BISO						
							(Th,U)O ₂ BISO	ThC ₂ BISO						
							(Th,U)O ₂ BISO	ThO ₂ BISO						
							UO ₂ BISO	ThO ₂ BISO						
	1	RTE-2	F07-06 ^(h)	No	No	Mixed (3 rods, 3 blended)	UC ₂ TRISO	ThC ₂ BISO						
							UC ₂ BISO	ThC ₂ BISO						
							(Th,U)O ₂ BISO	ThC ₂ BISO						
							(Th,U)O ₂ BISO	ThC ₂ BISO						
							UC ₂ TRISO	ThC ₂ BISO						
							UC ₂ BISO	ThC ₂ BISO						
							1	RTE-4	B10-06 ^(g)	No	No	Same as RTE-2	Same as RTE-2	Same as RTE-2

TABLE 1 (Continued)

Type	Phase ^(a)	Ident. Number	Core Position ^(b)	Thermo-Couples	Purge Sampling ^(c)	Fuel Bed	Fuel Particles	
							Fissile	Fertile
Fuel Test Elements								
Recycle test ↓	1	RTE-5	C10-06	No	No	Rods	UO ₂ BISO	ThC ₂ BISO
							(Th,U)O ₂ BISO	ThC ₂ BISO
							UC ₂ BISO	ThC ₂ BISO
							UC ₂ TRISO	ThC ₂ TRISO
							UC ₂ BISO	ThO ₂ BISO
							(Th,U)O ₂ BISO	ThC ₂ BISO
							(Th,U)O ₂ BISO	ThO ₂ BISO
							UC ₂ TRISO	ThC ₂ BISO
							UC ₂ BISO	ThO ₂ BISO
	1	RTE-6	D10-06	No	No	Rods	UO ₂ BISO	ThO ₂ BISO
							UC ₂ TRISO	ThC ₂ BISO
							(Th,U)O ₂ BISO	ThC ₂ BISO
							UC ₂ BISO	ThC ₂ BISO
							(Th,U)O ₂ BISO	ThC ₂ BISO
							(Th,U)O ₂ BISO	ThO ₂ BISO
							UC ₂ TRISO	ThC ₂ BISO
							UO ₂ BISO	ThO ₂ BISO
							UO ₂ BISO	ThC ₂ BISO
							UC ₂ BISO	ThO ₂ BISO
							(Th,U)O ₂ BISO	ThC ₂ BISO
	1	RTE-7	E10-06 ^(e)	No	No	Rods	UC ₂ TRISO	ThC ₂ TRISO

TABLE 1 (Continued)

Type	Phase ^(a)	Ident. Number	Core Position ^(b)	Thermo- Couples	Purge Sampling ^(c)	Fuel Bed	Fuel Particles	
							Fissile	Fertile
Fuel Test Elements								
Recycle test ↓	1	RTE-8	F10-06	No	No	Rods	UC ₂ TRISO	ThC ₂ BISO
							UC ₂ TRISO	ThC ₂ TRISO
							(Th,U)O ₂ BISO	ThC ₂ BISO
							UC ₂ BISO	ThC ₂ BISO
Proof Test Elements								
	1 ⁽ⁱ⁾	PTE-2	A07-07 ^(e)	Yes	No	Rods	(Th,U)C ₂ TRISO	ThC ₂ TRISO
Fuel Pin Test Elements								
	1	FPTE-1	E14-08 ^(e)	Yes	No	Compacts	(U-238)O ₂ TRISO	None
	2	FPTE-3	E14-08	Yes	No	Compacts	(U-238)O ₂ TRISO	None

(a) Phase 1 loaded at 0 EFPD of Core 2, Phase 2 loaded at 252 EFPD of Core 2, and Phase 3 loaded at 385 of Core 2.

(b) The core position shown is the last position in which the test element resided in the Peach Bottom core.

(c) An indication of purge sampling is relative only to the last position of the test element in the core.

(d) A fuel rod, as used here, is a close-packed assembly of coated fuel particles bonded together with a carbonaceous matrix.

TABLE 1 (Continued)

- (e) Removed during 252-EFPD Core 2 shutdown.
- (f) A blended bed, as used here, is a close-packed assembly of unbonded, coated fuel particles.
- (g) Removed during 385-EFPD Core 2 shutdown.
- (h) Removed during 701-EFPD Core 2 shutdown.
- (i) PTE-2 was irradiated 152 EFPD in Core 1 prior to irradiation in Core 2.

The overall design and test objectives of the fuel test element program were as follows:

1. To evaluate the irradiation performance of current and advanced fuel concepts over a wide range of reactor operating conditions and lifetimes.
2. To demonstrate satisfactory performance of a significant number of full-sized large HTGR fuel bed forms under actual reactor operating conditions.
3. To produce significant quantities of irradiated fuel for reprocessing studies.
4. To conduct controlled time/temperature irradiation experiments to determine:
 - a. Thermal stability of various types of coated particles.
 - b. Diffusion rates of metallic fission products.
 - c. Fission product release from various types of fuel particles.
 - d. Graphite mechanical and creep properties.
 - e. Irradiation behavior of advanced fuel rod concepts.

Figure 2 shows a general cross section of each type of fuel element (FTE, FTPE and PTE). An axial cross section of a typical fuel test element is shown in Fig. 3. In the FTE design, the fuel body configuration was constructed with three, six, or eight fuel holes in a "telephone dial" arrangement. A photograph of a typical FTE body is shown in Fig. 4.

3. REPORTED RESULTS ON THE TEST ELEMENT PROGRAM

3.1. GENERAL INFORMATION ON TEST ELEMENTS

The following GA reports provide general information on the Peach Bottom test element program:

<u>Title</u>	<u>Report No.</u>	<u>Ref.</u>
Objectives and Plans for Fuel Testing in the Peach Bottom Reactor	GA-10065	1
HTGR Fuel Performance in the Peach Bottom Reactor	Gulf-GA-A12675	2
Irradiation Experience With HTGR Fuels in the Peach Bottom Reactor	GA-A-12897	3
Thermal Analysis of Fuel Test Elements: A Summary of Analytical Techniques	GA-A19011	4
Summary Progress Report, GGA-EEI Study of Plutonium Utilization in the HTGR	GA-10271	5
Phase II - Final Progress Report, GGA-EEI Study of Plutonium Utilization in the HTGR	GA-10423	6

3.2. FABRICATION, ASSEMBLY, AND PREIRRADIATION EXAMINATION OF TEST ELEMENTS

The following reports are available on the design, fabrication, and preirradiation examination of the test elements listed.

<u>Test Element</u>	<u>Report Title</u>	<u>Report No.</u>	<u>Ref.</u>
FPTE-1	Assembly and Preirradiation Examination of Fuel Pin Test Element No. 1	GA-10254	7
All phase 1 test elements*	Fuel Test Element Program, Assembly of GGA Phase-1 Test Elements	--	8
Spine samples for all phase 1 and 2 test elements*	Spine Samples in the Phase 1 and Phase 2 Peach Bottom Test Elements	--	9
RTE-2, -4, -5, -6, -7, -8 and FTE-11	Recycle Test Element Program Design, Fabrication, and Assembly	GA-10109	10
RTE-4, -7	Fabrication of ORNL Fuel Irradiated in the Peach Bottom Reactor and Postirradiation Examination of Recycle Test Elements 7 and 4	ORNL-TM-4477	11
FPTE-3	Assembly and Preirradiation Examination of Fuel Pin Test Element No. 3	Gulf-GA-A10910	12
FTE-14, -15	Design and Operational Evaluation for Fuel Test Elements No. 14 and 15	Gulf-GA-B12344	13
PTE-2	Fort St. Vrain Test Element No. Two Design, Fabrication, and Assembly Report	Gulf-GA-B12340	14
FTE-18	Design and Operational Evaluation for Fuel Test Element No. 18	--	15
FTE-13	Phase III - Final Progress Report, Part I of Two Parts, Design and Operational Evaluation for Plutonium Test Element (FTE-13)	Gulf-GA-B12271	16
FTE-13	Phase III - Final Progress Report, Part II of Two Parts, Design and Fabrication of the Plutonium Fuels for the Plutonium Fuel Test Element (FTE-13)	Gulf-GA-B12288	17
FTE-13	Fabrication and Characteristics of Plutonium Test FTE-13: An HTGR Test Element Containing PuO_{2-x} , $\text{Th}_{0.25}\text{Pu}_{0.25}\text{O}_{2-x}$, and ThO_2 .	ORNL-TM-4207	18

*See Fig. 1 for phase definition.

3.3. POSTIRRADIATION EXAMINATION OF TEST ELEMENTS

The following GA reports are available on the postirradiation examination results for the test elements listed.

<u>Test Element</u>	<u>Report Title</u>	<u>Report No.</u>	<u>Ref.</u>
FPTE-1	Postirradiation Examination of Fuel Pin Test Element No. 1	Gulf-GA-A12109	19
FPTE-1	The Irradiation of MK3 HTGR Fuel in Peach Bottom HTGC Reactor; Irradiation History of the Lead Experiment IE 486/1	TRG Report 2201(S)	20
FPTE-1	MK3 Hollow Rod Fuel Irradiation in Peach Bottom HTGC Reactor, IE 486/1 Preliminary Results	TRG Memorandum 6333(S)	21
FPTE-3	Postirradiation Examination of Peach Bottom Fuel Pin Test Element FPTE-3	GA-A13849	22
FPTE-3	The Irradiation of MK3 HTR Fuel in Peach Bottom HTGC Reactor, Irradiation History of Main Experiment, IE 486/3	TRG Report 2748(S)	23
FTE-3	Postirradiation Examination of Peach Bottom Fuel Test Element FTE-3	GA-A13004	24
FTE-4	Postirradiation Examination of Peach Bottom Fuel Test Element FTE-4	GA-A13452	25
FTE-18	Postirradiation Examination of Peach Bottom Fuel Test Element FTE-18	GA-A13699	26
RTE-7, -4	Fabrication of ORNL Fuel Irradiated in the Peach Bottom Reactor and Postirradiation Examination of Recycle Test Elements 7 and 4	ORNL-TM-4477	11
RTE-7	Head-End Reprocessing Studies With Irradiated HTGR-type Fuels: III. Studies with RTE-7: TRISO UC ₂ - TRISO ThC ₂	ORNL-5090	27

4. TEST ELEMENT FISSION GAS RELEASE

The test element program, as described previously, included 13 purged elements for monitoring fission gas release from the fuel as a function of burnup. Table 2 lists the elements tested in this manner along with the core location, fuel type, and irradiation time. A wide variety of fuel specimens was tested mainly to provide information concerning large HTGR [3000 MW(t)] fuel behavior. The purge gas was monitored as frequently as possible during irradiation.

Figures 5 through 95 are plots of fission gas release R/B data obtained as a function of effective full power days (EFPD) of test element operation in the purged mode. The noble gas isotopes monitored were Kr-85m, -87, -88, and -89 and Xe-133, -135, and -138. Several test elements were purged for a relatively short time and then moved to a nonpurged location (FTE-5, for instance). This allowed obtaining an initial R/B value early in life. Postirradiation examination was then conducted on these elements, including TRIGA fission gas release tests, to evaluate end-of-life performance. All other test elements irradiated only in the purge mode were not examined after irradiation. Fuel performance evaluation will be reported in other documents upon completion of PIE.

During the final phase of the irradiation program, test elements FTE-7, -8, -9, -10, -12, -16, and -17 and FBTE-3 were monitored for fission gas release as a function of power level (percent maximum power). These data were then used to assist in evaluation of fuel performance. Figures 96 through 135 show the R/B data obtained at various reactor power levels. The noble gases Kr-85m, -87, and -88 and Xe-133 and -135 were monitored for each test element. The data indicate a general increase in R/B with increasing power or, more correctly, increasing temperature. Earlier TRIGA irradiation tests on fresh and irradiated fuels have shown similar temperature dependence.

TABLE 2
PEACH BOTTOM PURGED TEST ELEMENTS

Element	Core Location	Fuel Particle Type		Irradiation Time (EFPD)	
		Fissile	Fertile	Purged	Total
FTE-5	D14-08	UC ₂ BISO and TRISO (Th,U)C ₂ TRISO	ThC ₂ BISO and TRISO	252	897
FTE-7	F14-08	UO ₂ TRISO	ThO ₂ BISO	653	653
FTE-8	D14-08	UC ₂ TRISO	ThC ₂ BISO	653	653
FTE-9	E02-01 (D06-01)	(Th,U)C ₂ TRISO	ThC ₂ BISO	653	653
FTE-10 (PTE-3)	B06-01 (E02-01)	(Th,U)C ₂ TRISO	ThC ₂ TRISO	653	653
FTE-12	F06-01 (B06-01)	(Th,U)O ₂ BISO	ThO ₂ BISO	653	653
FTE-16 (PTE-4)	F06-01	(Th,U)C ₂ TRISO	ThC ₂ TRISO	512	512
FTE-17 (PTE-5)	A02-01	(Th,U)C ₂ TRISO	ThC ₂ TRISO	512	512
FBTE-1	A02-01	(Th,U)C ₂ BISO	ThC ₂ BISO	385	897
FBTE-2	D06-01	UC ₂ BISO	ThC ₂ BISO	385	897
FBTE-3	B14-08	UC ₂ TRISO	ThC ₂ BISO	897	897
FBTE-4	F06-01	(Th,U)C ₂ TRISO	ThC ₂ TRISO	252	252
FBTE-6	F14-08	(Th,U)C ₂ BISO	ThC ₂ BISO	252	252

The data given for all test elements have not been corrected for the effect of burnup or fissile fuel depletion. Time-dependent fissile loading will be calculated and incorporated into final R/B values to be reported in other documents.

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Fig. 1. Schedule for Peach Bottom Core 2 test element irradiations

Fig. 2. Cross sections of test element classes

Fig. 3. Typical fuel test element assembly

Fig. 4. Typical fuel test element fuel body

Fig. 5. Fuel test element FTE-5, Kr-85m fission gas release R/B data

Fig. 6. Fuel test element FTE-5, Kr-87 fission gas release R/B data

Fig. 7. Fuel test element FTE-5, Kr-88 fission gas release R/B data

Fig. 8. Fuel test element FTE-5, Kr-89 fission gas release R/B data

Fig. 9. Fuel test element FTE-5, Xe-133 fission gas release R/B data

Fig. 10. Fuel test element FTE-5, Xe-135 fission gas release R/B data

Fig. 11. Fuel test element FTE-5, Xe-138 fission gas release R/B data

Fig. 12. Fuel test element FTE-7, Kr-85m fission gas release R/B data

Fig. 13. Fuel test element FTE-7, Kr-87 fission gas release R/B data

Fig. 14. Fuel test element FTE-7, Kr-88 fission gas release R/B data

Fig. 15. Fuel test element FTE-7, Kr-89 fission gas release R/B data

Fig. 16. Fuel test element FTE-7, Xe-133 fission gas release R/B data

Fig. 17. Fuel test element FTE-7, Xe-135 fission gas release R/B data

Fig. 18. Fuel test element FTE-7, Xe-138 fission gas release R/B data

Fig. 19. Fuel test element FTE-8, Kr-85m fission gas release R/B data

Fig. 20. Fuel test element FTE-8, Kr-87 fission gas release R/B data

Fig. 21. Fuel test element FTE-8, Kr-88 fission gas release R/B data

Fig. 22. Fuel test element FTE-8, Kr-89 fission gas release R/B data

Fig. 23. Fuel test element FTE-8, Xe-133 fission gas release R/B data

Fig. 24. Fuel test element FTE-8, Xe-135 fission gas release R/B data

Fig. 25. Fuel test element FTE-8, Xe-138 fission gas release R/B data

Fig. 26. Fuel test element FTE-9, Kr-85m fission gas release R/B data

Fig. 27. Fuel test element FTE-9, Kr-87 fission gas release R/B data

Fig. 29. Fuel test element FTE-9, Kr-89 fission gas release R/B data

Fig. 30. Fuel test element FTE-9, Xe-133 fission gas release R/B data

Fig. 31. Fuel test element FTE-9, Xe-135 fission gas release R/B data

Fig. 32. Fuel test element FTE-9, Xe-138 fission gas release R/B data

Fig. 33. Fuel test element FTE-10, Kr-85m fission gas release R/B data

Fig. 34. Fuel test element FTE-10, Kr-87 fission gas release R/B data

Fig. 35. Fuel test element FTE-10, Kr-88 fission gas release R/B data

Fig. 36. Fuel test element FTE-10, Kr-89 fission gas release R/B data

Fig. 37. Fuel test element FTE-10, Xe-133 fission gas release R/B data

Fig. 38. Fuel test element FTE-10, Xe-135 fission gas release R/B data

Fig. 39. Fuel test element FTE-10, Xe-138 fission gas release R/B data

Fig. 40. Fuel test element FTE-12, Kr-85m fission gas release R/B data

Fig. 41. Fuel test element FTE-12, Kr-87 fission gas release R/B data

Fig. 42. Fuel test element FTE-12, Kr-88 fission gas release R/B data

Fig. 43. Fuel test element FTE-12, Kr-89 fission gas release R/B data

Fig. 44. Fuel test element FTE-12, Xe-133 fission gas release R/B data

Fig. 45. Fuel test element FTE-12, Xe-135 fission gas release R/B data

Fig. 46. Fuel test element FTE-12, Xe-138 fission gas release R/B data

Fig. 47. Fuel test element FTE-16, Kr-85m fission gas release R/B data

Fig. 48. Fuel test element FTE-16, Kr-87 fission gas release R/B data

Fig. 49. Fuel test element FTE-16, Kr-88 fission gas release R/B data

Fig. 50. Fuel test element FTE-16, Kr-89 fission gas release R/B data

Fig. 51. Fuel test element FTE-16, Xe-133 fission gas release R/B data

Fig. 52. Fuel test element FTE-16, Xe-135 fission gas release R/B data

Fig. 53. Fuel test element FTE-16, Xe-138 fission gas release R/B data

Fig. 54. Fuel test element FTE-17, Kr-85m fission gas release R/B data

Fig. 55. Fuel test element FTE-17, Kr-87 fission gas release R/B data

Fig. 56. Fuel test element FTE-17, Kr-88 fission gas release R/B data

Fig. 57. Fuel test element FTE-17, Kr-89 fission gas release R/B data

Fig. 58. Fuel test element FTE-17, Xe-133 fission gas release R/B data

Fig. 59. Fuel test element FTE-17, Xe-135 fission gas release R/B data

Fig. 60. Fuel test element FTE-17, Xe-138 fission gas release R/B data

Fig. 61. Fuel bed test element FBTE-1, Kr-85m fission gas release R/B data

Fig. 62. Fuel bed test element FBTE-1, Kr-87 fission gas release R/B data

Fig. 63. Fuel bed test element FBTE-1, Kr-88 fission gas release R/B data

Fig. 64. Fuel bed test element FBTE-1, Kr-89 fission gas release R/B data

Fig. 65. Fuel bed test element FBTE-1, Xe-133 fission gas release R/B data

Fig. 66. Fuel bed test element FBTE-1, Xe-135 fission gas release R/B data

Fig. 67. Fuel bed test element FBTE-1, Xe-138 fission gas release R/B data

Fig. 68. Fuel bed test element FBTE-2, Kr-85m fission gas release R/B data

Fig. 69. Fuel bed test element FBTE-2, Kr-87 fission gas release R/B data

Fig. 70. Fuel bed test element FBTE-2, Kr-88 fission gas release R/B data

Fig. 71. Fuel bed test element FBTE-2, Kr-89 fission gas release R/B data

Fig. 72. Fuel bed test element FBTE-2, Xe-133 fission gas release R/B data

Fig. 73. Fuel bed test element FBTE-2, Xe-135 fission gas release R/B data

Fig. 74. Fuel bed test element FBTE-2, Xe-138 fission gas release R/B data

Fig. 75. Fuel bed test element FBTE-3, Kr-85m fission gas release R/B data

Fig. 76. Fuel bed test element FBTE-3, Kr-87 fission gas release R/B data

Fig. 77. Fuel bed test element FBTE-3, Kr-88 fission gas release R/B data

Fig. 78. Fuel bed test element FBTE-3, Kr-89 fission gas release R/B data

Fig. 79. Fuel bed test element FBTE-3, Xe-133 fission gas release R/B data

Fig. 80. Fuel bed test element FBTE-3, Xe-135 fission gas release R/B data

Fig. 81. Fuel bed test element FBTE-3, Xe-138 fission gas release R/B data

Fig. 82. Fuel bed test element FBTE-4, Kr-85m fission gas release R/B data

Fig. 83. Fuel bed test element FBTE-4, Kr-87 fission gas release R/B data

Fig. 84. Fuel bed test element FBTE-4, Kr-88 fission gas release R/B data

Fig. 85. Fuel bed test element FBTE-4, Kr-89 fission gas release R/B data

Fig. 86. Fuel bed test element FBTE-4, Xe-133 fission gas release R/B data

Fig. 87. Fuel bed test element FBTE-4, Xe-135 fission gas release R/B data

Fig. 88. Fuel bed test element FBTE-4, Xe-138 fission gas release R/B data

Fig. 89. Fuel bed test element FBTE-6, Kr-85m fission gas release R/B data

Fig. 90. Fuel bed test element FBTE-6, Kr-87 fission gas release R/B data

Fig. 91. Fuel bed test element FBTE-6, Kr-88 fission gas release R/B data

Fig. 93. Fuel bed test element FBTE-6, Xe-133 fission gas release R/B data

Fig. 94. Fuel bed test element FBTE-6, Xe-135 fission gas release R/B data

Fig. 95. Fuel bed test element FBTE-6, Xe-138 fission gas release R/B data

Fig. 96. Fuel test element FTE-7 (F14-08) R/B as a function of power, Kr-85m

Fig. 97. Fuel test element FTE-7 (F14-08) R/B as a function of power, Kr-87

Fig. 98. Fuel test element FTE-7 (F14-08) R/B as a function of power, Kr-88

Fig. 99. Fuel test element FTE-7 (F14-08) R/B as a function of power, Xe-133

Fig. 100. Fuel test element FTE-7 (F14-08) R/B as a function of power, Xe-135

Fig. 101. Fuel test element FTE-8 (D14-08) R/B as a function of power, Kr-85m

Fig. 102. Fuel test element FTE-8 (D14-08) R/B as a function of power, Kr-87

Fig. 103. Fuel test element FTE-8 (D14-08) R/B as a function of power, Kr-88

Fig. 104. Fuel test element FTE-8 (D14-08) R/B as a function of power, Xe-133

Fig. 105. Fuel test element FTE-8 (D14-08) R/B as a function of power, Xe-135

Fig. 106. Fuel test element FTE-9 (D06-01) R/B as a function of power, Kr-85m

Fig. 107. Fuel test element FTE-9 (D06-01) R/B as a function of power, Kr-87

Fig. 108. Fuel test element FTE-9 (D06-01) R/B as a function of power, Kr-88

Fig. 109. Fuel test element FTE-9 (D06-01) R/B as a function of power, Xe-133

Fig. 110. Fuel test element FTE-9 (D06-01) R/B as a function of power, Xe-135

Fig. 111. Fuel test element FTE-10 (E02-01) R/B as a function of power, Kr-85m

Fig. 112. Fuel test element FTE-10 (E02-01) R/B as a function of power, Kr-87

Fig. 113. Fuel test element FTE-10 (E02-01) R/B as a function of power, Kr-88

Fig. 114. Fuel test element FTE-10 (E02-01) R/B as a function of power, Xe-133

Fig. 115. Fuel test element FTE-10 (E02-01) R/B as a function of power, Xe-135

Fig. 116. Fuel test element FTE-12 (B06-01) R/B as a function of power, Kr-85m

Fig. 117. Fuel test element FTE-12 (B06-01) R/B as a function of power, Kr-87

Fig. 118. Fuel test element FTE-12 (B06-01) R/B as a function of power, Kr-88

Fig. 119. Fuel test element FTE-12 (B06-01) R/B as a function of power, Xe-133

Fig. 120. Fuel test element FTE-12 (B06-01) R/B as a function of power, Xe-135

Fig. 121. Fuel test element FTE-16 (F06-01) R/B as a function of power, Kr-85m

Fig. 122. Fuel test element FTE-16 (F06-01) R/B as a function of power, Kr-87

Fig. 123. Fuel test element FTE-16 (F06-10) R/B as a function of power, Kr-88

Fig. 124. Fuel test element FTE-16 (F06-01) R/B as a function of power, Xe-133

Fig. 125. Fuel test element FTE-16 (F06-01) R/B as a function of power, Xe-135

Fig. 126. Fuel test element FTE-17 (A02-01) R/B as a function of power, Kr-85m

Fig. 127. Fuel test element FTE-17 (A02-01) R/B as a function of power, Kr-87

Fig. 128. Fuel test element FTE-17 (A02-01) R/B as a function of power, Kr-88

Fig. 129. Fuel test element FTE-17 (A02-01) R/B as a function of power, Xe-133

Fig. 130. Fuel test element FTE-17 (A02-01) R/B as a function of power, Xe-135

Fig. 131. Fuel bed test element FBTE-3 (B14-08) R/B as a function of power, Kr-85m

Fig. 132. Fuel bed test element FBTE-3 (B14-08) R/B as a function of power, Kr-87

Fig. 133. Fuel bed test element FBTE-3 (B14-08) R/B as a function of power, Kr-88

Fig. 134. Fuel bed test element FBTE-3 (B14-08) R/B as a function of power, Xe-133

Fig. 135. Fuel bed test element FBTE-3 (B14-08) R/B as a function of power, Xe-135