

**Fig.E-10.4. Cladding microstructure of fuel rod # RT10 at 33 mm elevation (from low cap)**

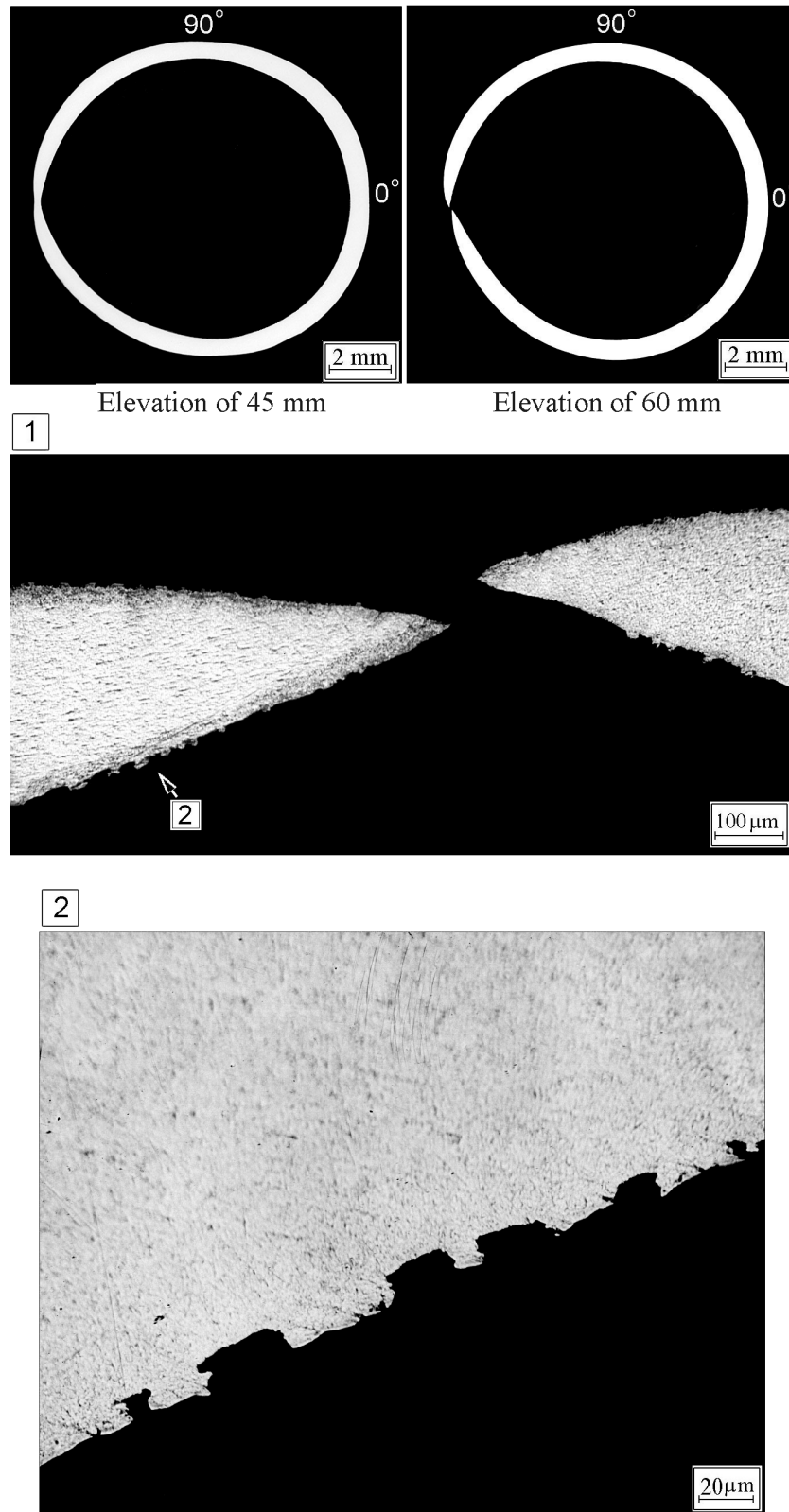


Fig.E-10.5. Cladding cross-sections at elevations 45 and 60 mm and cladding microstructure at 60 mm elevation (from low cap) for fuel rod # RT10

**Table E-10.1. Time dependent energy characteristics of fuel rod # RT10**

Time (s)	Relative reactor power (current/ maximum value) (per-unit)	Cumulative number of fissions in fuel rod (fiss) x10 <sup>-14</sup>	Power of fuel rod <sup>1)2)</sup> (kW)	Energy deposition		Fuel enthalpy <sup>3)</sup>	
				(cal/g fuel)	(J/g fuel)	FRAP-T6	RAPTA-5
0.000	0.00E+00	0.000	0.000	0.000	0.000	0.000	0.000
0.001	9.16E-03	0.140	75.14	0.151	0.634	0.671	0.008
0.002	4.13E-02	0.748	338.9	0.811	3.397	0.671	0.048
0.003	1.85E-01	3.508	1516	3.803	15.92	0.671	0.195
0.004	6.20E-01	14.31	5085	15.52	64.96	1.091	0.805
0.005	9.98E-01	39.15	8186	42.50	177.9	4.076	3.976
0.006	6.84E-01	64.62	5613	70.07	293.4	15.499	15.977
0.007	3.18E-01	78.53	2607	85.21	356.7	41.590	42.989
0.008	1.50E-01	84.89	1229	92.13	385.7	68.273	70.367
0.009	8.59E-02	88.17	705.1	95.67	400.5	82.848	85.261
0.010	6.22E-02	90.27	510.7	97.93	410.0	89.376	91.781
0.012	5.26E-02	93.44	431.1	101.4	424.4	94.495	96.818
0.014	5.67E-02	96.53	465.2	104.8	438.6	97.283	99.638
0.016	6.50E-02	99.88	533.4	108.6	454.5	100.010	102.487
0.018	6.93E-02	103.8	568.7	112.8	472.3	103.191	105.803
0.020	6.68E-02	107.7	547.9	117.1	490.1	106.810	109.590
0.022	5.90E-02	111.6	484.4	121.0	506.6	110.476	113.402
0.024	5.04E-02	114.6	413.3	124.5	521.1	113.842	116.911
0.026	4.19E-02	117.4	343.9	127.4	533.2	116.717	119.900
0.028	3.51E-02	119.5	288.4	129.7	543.2	119.070	122.357
0.030	3.09E-02	121.4	253.4	131.8	551.8	120.976	124.333
0.050	2.64E-02	137.3	217.2	149.1	624.3	134.540	138.386
0.070	2.21E-02	151.7	181.6	164.5	688.6	146.907	150.845
0.090	1.54E-02	162.6	126.8	176.3	738.0	154.873	160.149
0.110	6.66E-03	168.8	54.79	183.1	766.6	160.862	165.043
0.130	2.39E-03	170.9	19.80	185.7	777.4	162.471	165.870
0.150	1.23E-03	171.9	10.33	186.8	782.2	162.444	165.233
0.200	4.18E-04	172.9	3.614	188.0	787.1	160.937	162.802
1.000	6.97E-05	175.6	0.700	191.2	800.5	148.795	147.640
10.00	8.13E-06	181.6	0.093	199.5	835.3	61.291	66.612
100.0	1.64E-07	184.5	0.004	204.8	857.5	6.053	10.345
1000	6.45E-13	184.6	1.65E-04	206.7	865.2	0.000	0.000

<sup>1)</sup> Average values determined in accordance with results of RRC KI and VNIIEF calculations<sup>2)</sup> Maximum power value is 8204 kW (t=0.00491 s)<sup>3)</sup> Average radial value

## # RT10

**Table E-10.2. Radial energy characteristics of fuel rod # RT10\***

Parameters	Coordinates of fuel radial layers (mm)			
	1 layer	2 layer	3 layer	4 layer
	(1.250-2.834)	(2.834-3.452)	(3.452-3.722)	(3.722-3.808)
Number of fissions $\times 10^{-14}$ (fiss)	8.317	5.305	3.238	1.607
Fission density $\times 10^{-13}$ (fiss/g fuel)	2.657	2.824	3.452	5.122
Power ** (kW)	3688	2356	1442	718.6
Energy deposition (cal/g fuel)	185.8	197.7	242.4	360.8
Energy deposition (J/g fuel)	778.1	827.8	1015	1511
Energy deposition *** (per-unit)	0.515	0.548	0.672	1.000

\* Average values were determined in accordance with results of RRC KI and VNIIEF calculations

\*\* The power for the entire length of each layer at time 0.00491 s

\*\*\* Energy deposition in current layer/energy deposition in 4<sup>th</sup> layer



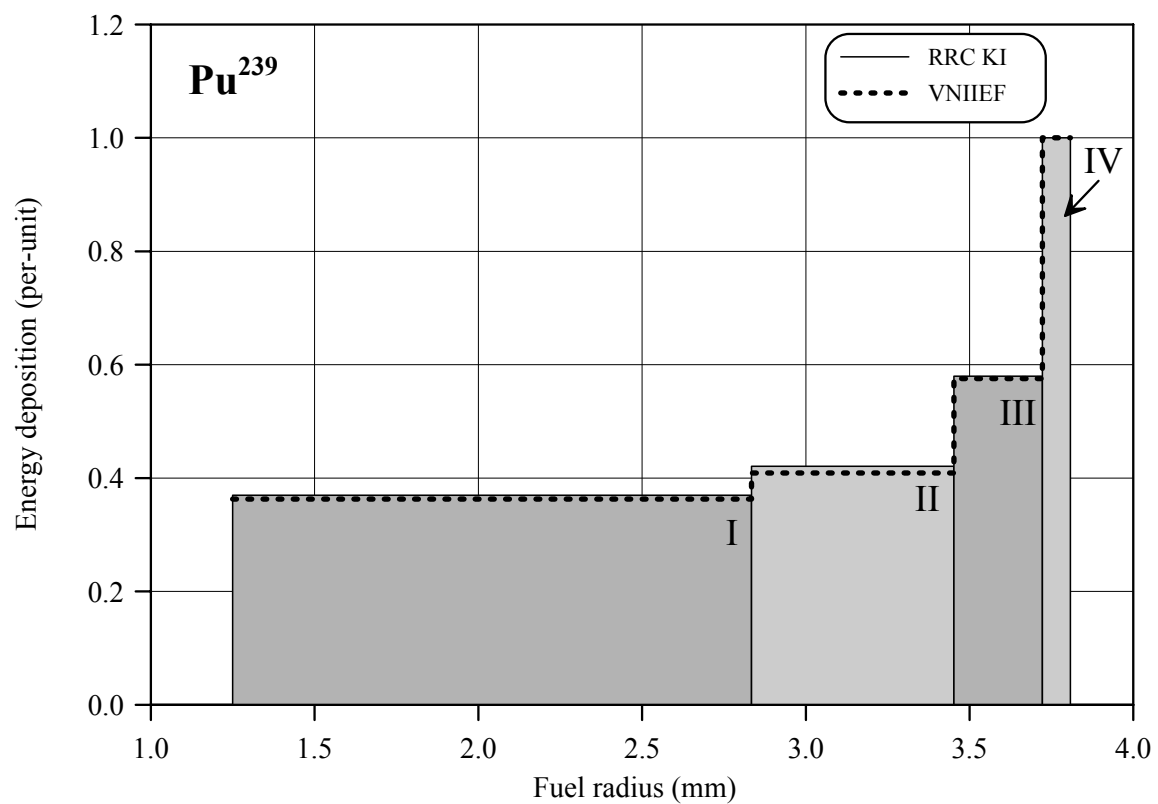
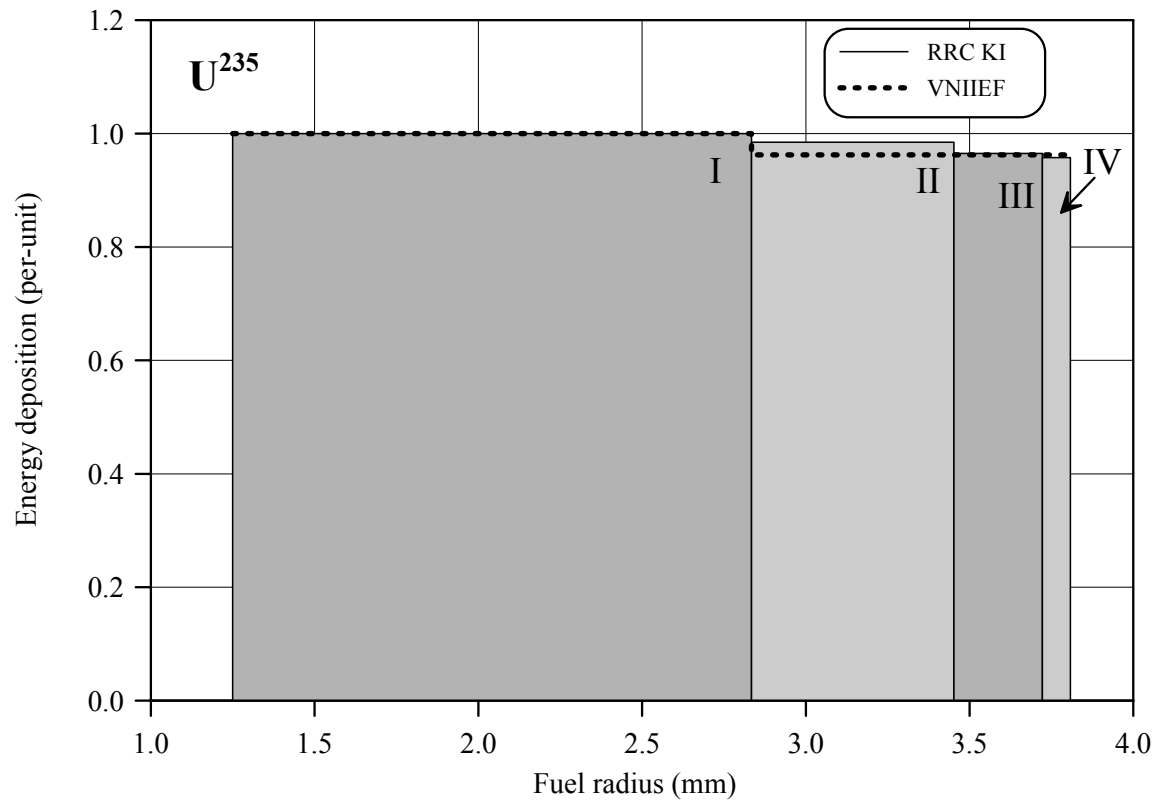


Fig.E-10.6. U<sup>235</sup> and Pu<sup>239</sup> radial distribution of energy deposition for fuel rod # RT10

# # RT10

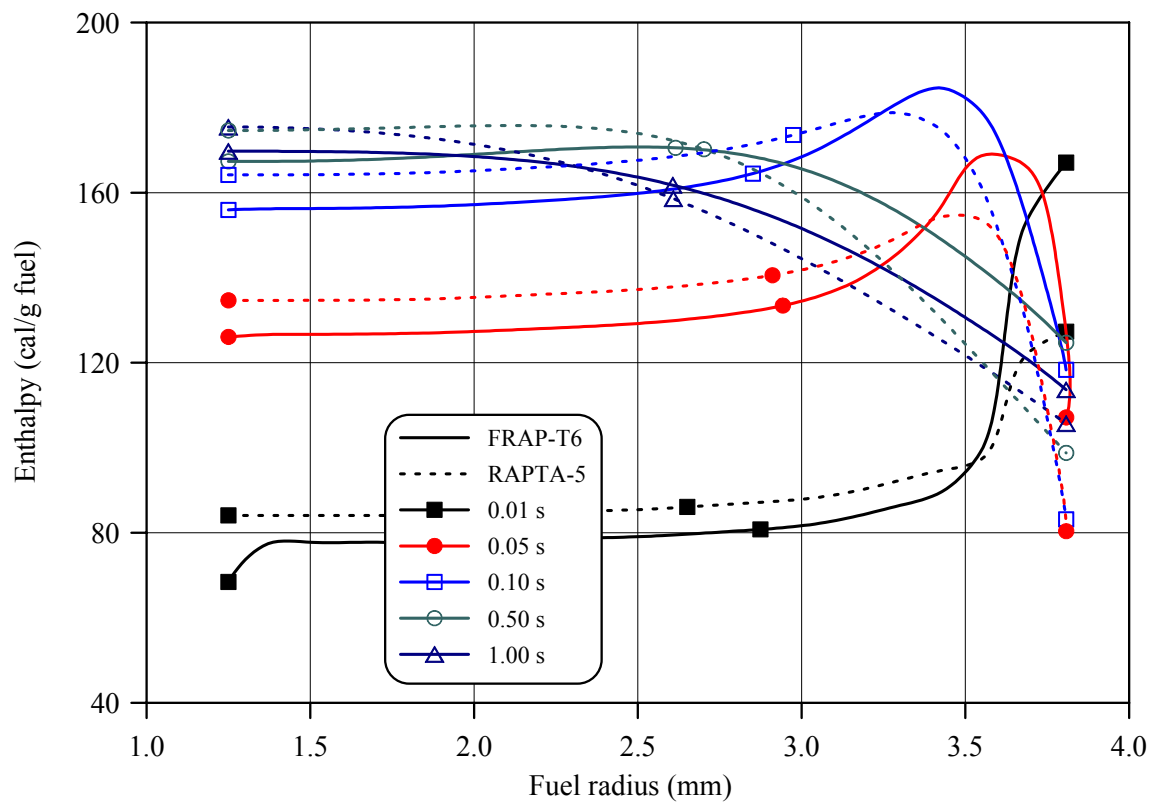
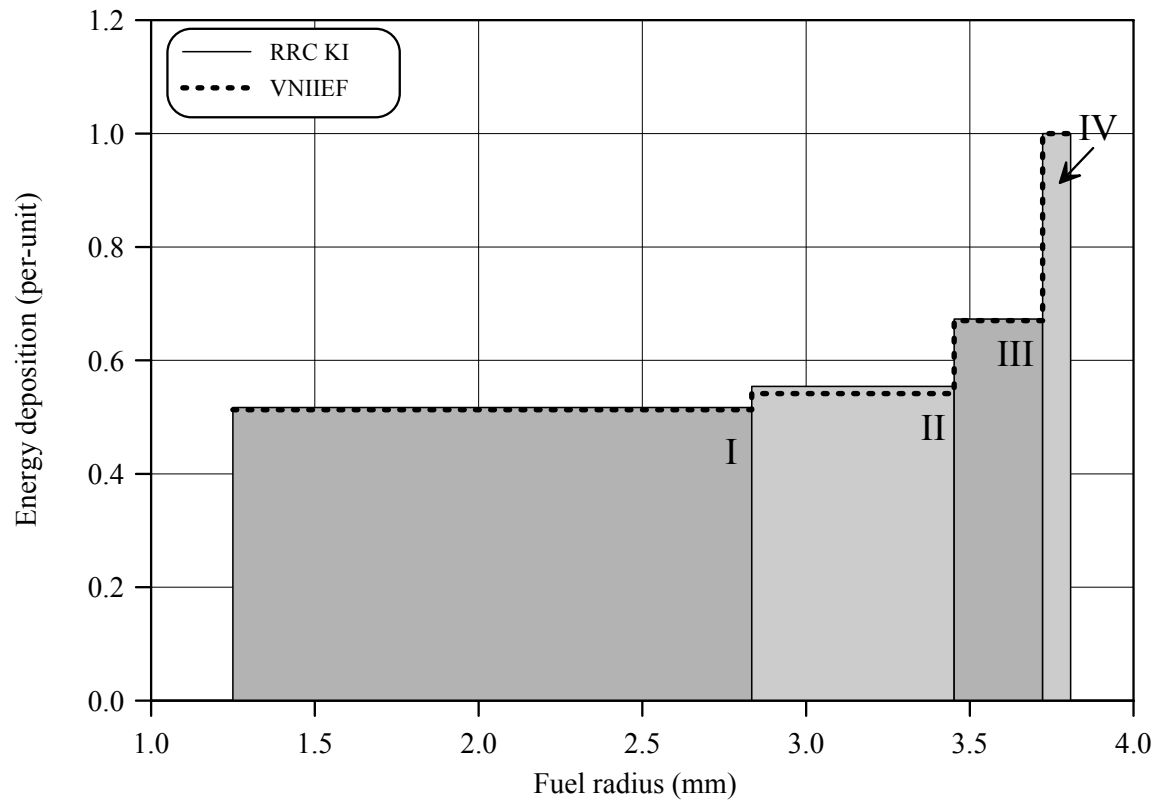


Fig.E-10.7. Radial distribution of energy deposition and fuel enthalpy for fuel rod # RT10

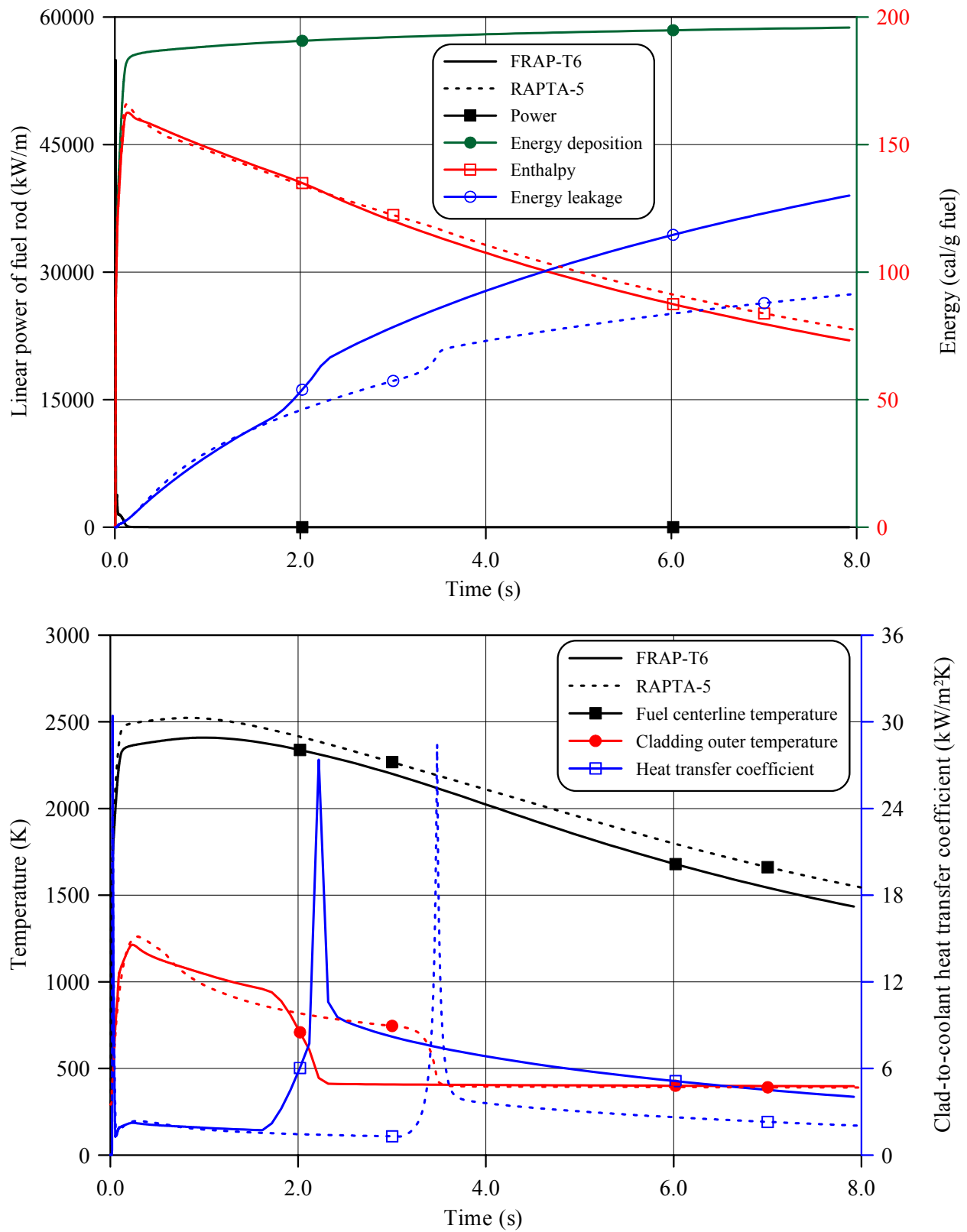
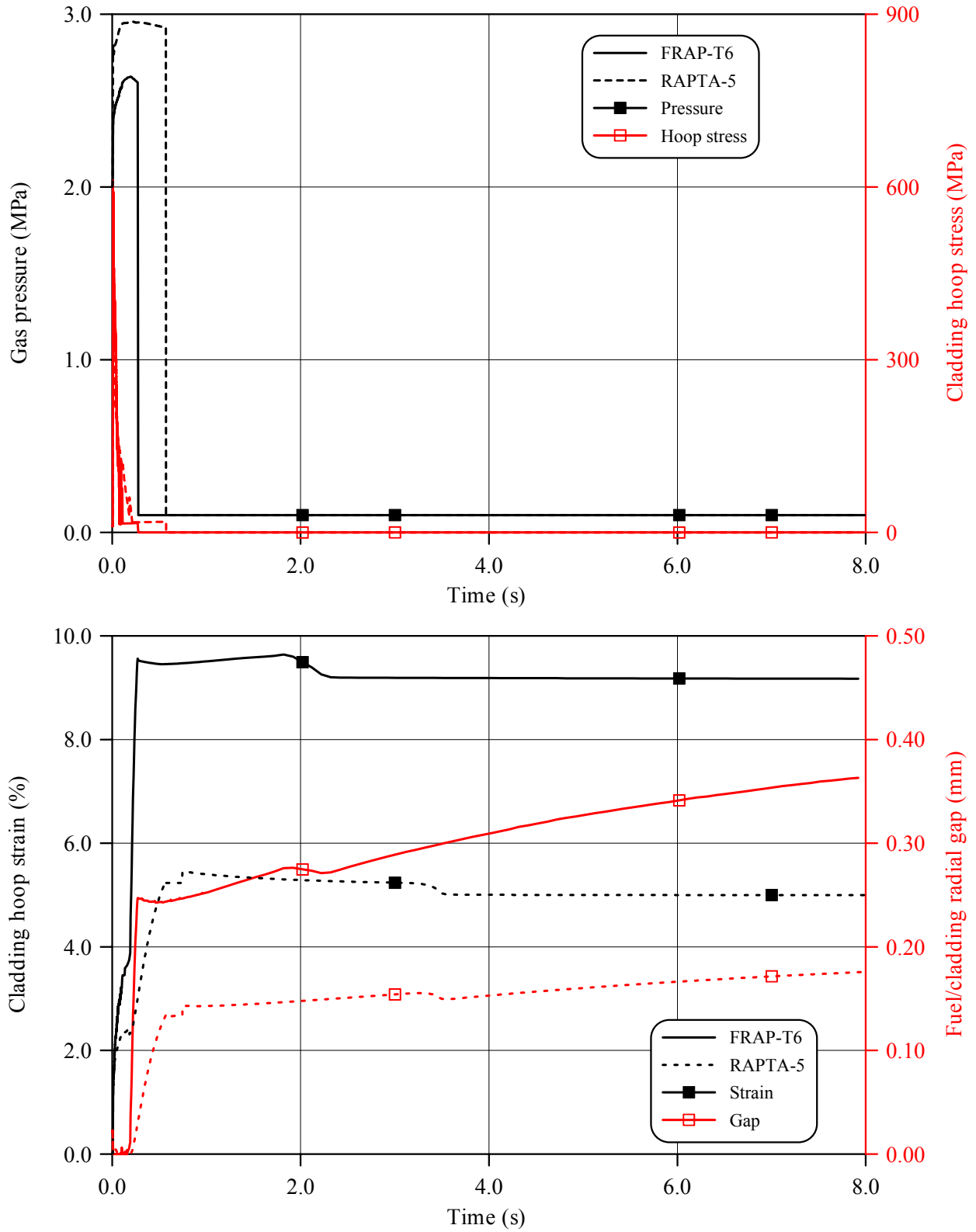


Fig.E-10.8. Thermal history of fuel rod # RT10 during the BGR test in accordance with FRAP-T6/VVER and RAPTA-5 calculations

# # RT10



**Fig.E-10.9. Mechanical behavior of fuel rod # RT10 during the B1GR test in accordance with FRAP-T6/VVER and RAPTA-5 calculations**

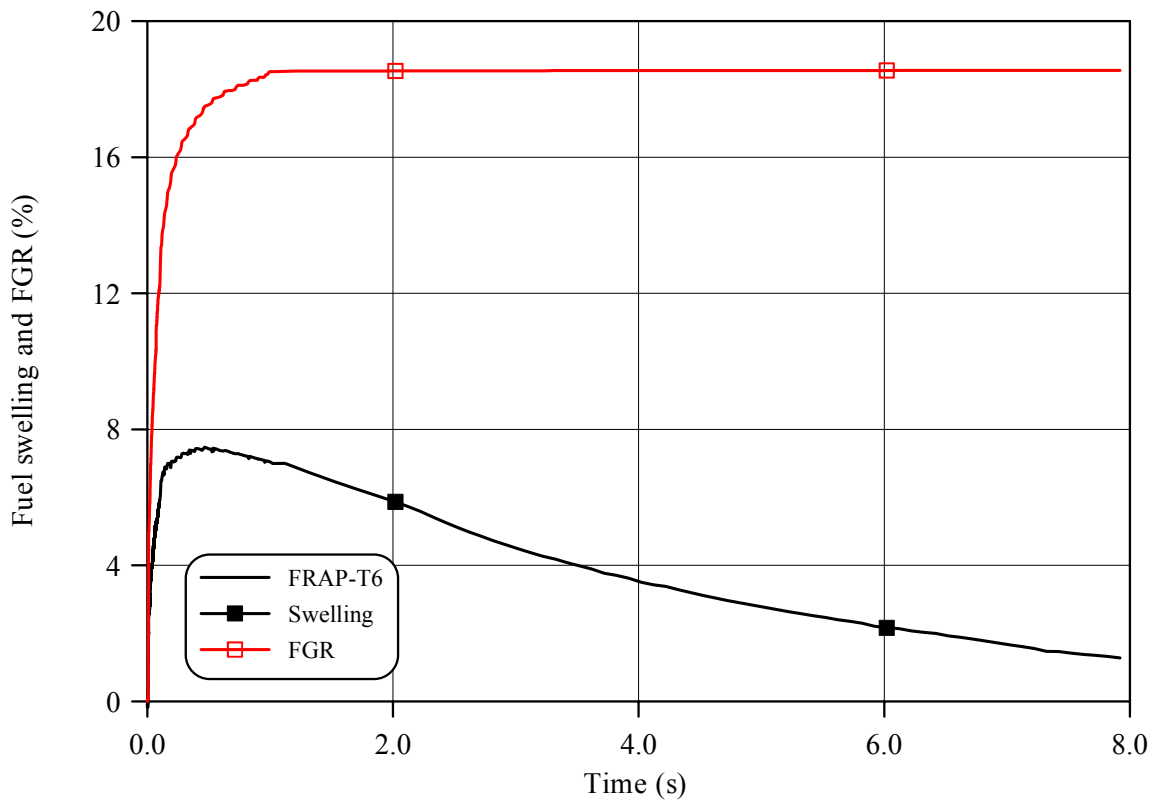
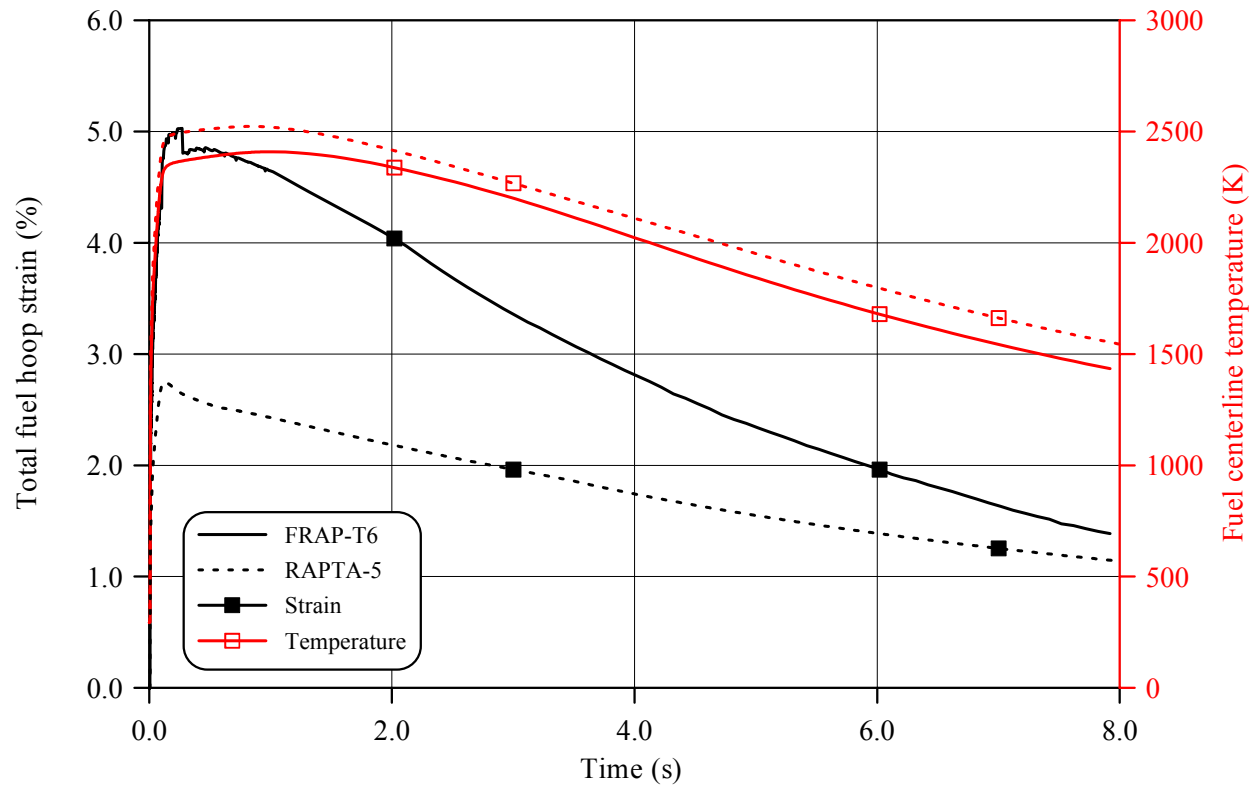


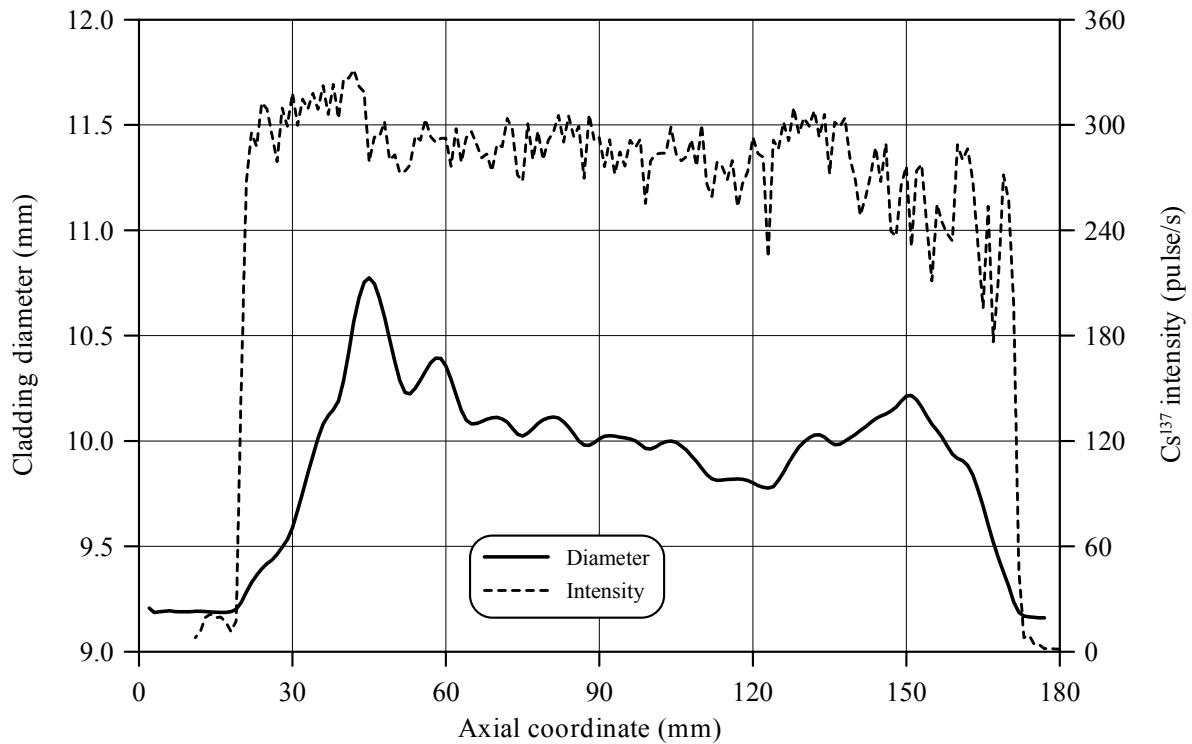
Fig.E-10.10. Fuel behavior during the BGR test of fuel rod # RT10 in accordance with FRAP-T6/VVER and RAPTA-5 calculations

# # RT10

**Table E-10.3. Axial distribution of cladding average outer diameter in fuel rod # RT10\***

Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)
24	9.394	62	10.219	100	9.962	138	9.999
26	9.435	64	10.099	102	9.987	140	10.031
28	9.496	66	10.084	104	10.000	142	10.068
30	9.588	68	10.104	106	9.976	144	10.106
32	9.755	70	10.112	108	9.930	146	10.129
34	9.931	72	10.090	110	9.871	148	10.161
36	10.081	74	10.033	112	9.821	150	10.213
38	10.149	76	10.037	114	9.814	152	10.197
40	10.284	78	10.084	116	9.819	154	10.118
42	10.566	80	10.110	118	9.819	156	10.050
44	10.754	82	10.109	120	9.802	158	9.977
46	10.747	84	10.066	122	9.781	160	9.918
48	10.588	86	10.000	124	9.784	162	9.885
50	10.377	88	9.979	126	9.852	164	9.771
52	10.230	90	10.011	128	9.936	166	9.604
54	10.250	92	10.025	130	9.996	168	9.444
56	10.330	94	10.018	132	10.028	170	9.311
58	10.394	96	10.010	134	10.020	172	9.186
60	10.356	98	9.984	136	9.983	174	9.166

\* Measured value determined on the basis of profilometry data (16 azimuthal directions)



**Fig.E-10.11. Cladding measured average diameter and  $\gamma$ -scanning results for fuel rod # RT10**

Table E-10.4. The PIE results for fuel rod # RT10

Parameter		Value
1.	Cladding outer diameter (mm):	
1.1.	Maximum diameter of the bidimensional data sample in "fuel rod length - azimuthal angle" coordinates (mm)	11.03
1.2.	Averaged azimuthal diameter and maximum diameter along the length selected from the sample of averaged azimuthal diameter (mm)	10.75
1.3.	Averaged diameter of the bidimensional data sample in "fuel rod length - azimuthal angle" coordinates (mm)	9.88
2.	Cladding residual hoop strain (%):	
2.1.	Maximum hoop strain	18.90
2.2.	Hoop strain at rupture	14.75
3.	Fuel pellet conditional diameter (mm) in cross-section*:	
	at 33 mm elevation	8.19
4.	ZrO <sub>2</sub> outer thickness (μm) in cross-section:	
	at 33, 45, 60 mm elevations	4–7
5.	ZrO <sub>2</sub> inner thickness (μm) in cross-section:	
	at 45, 60 mm elevations	0
6.	Parameters characterizing FGR:	
6.1.	Gas composition (% by volume):	
	He	-
	N <sub>2</sub>	-
	O <sub>2</sub>	-
	Ar	-
	CO <sub>2</sub>	-
	Kr	-
	Xe	-
6.2.	Free gas volume (cm <sup>3</sup> )	-
6.3.	Gas volume under normal conditions (cm <sup>3</sup> )	-
6.4.	Gas pressure under normal conditions (MPa)	-

\* Reference value determined by the processing of fuel cross-section photographs

# # RT10

**Table E-10.5. Organized BGR test results for fuel rod # RT10**

	Parameter	Unit	Value		
			Measured	Calculated	
				FRAP-T6	RAPTA-5
1.	Fuel burnup	MW d/kg U	47.0	47.0	47.0
2.	Initial gas pressure	MPa	2.0	2.0	2.0
3.	Energy deposition	cal/g fuel	206.7	206.7	206.7
4.	Peak fuel enthalpy*	cal/g fuel	-	162.5	165.9
5.	Fuel maximum temperature	K	-	2542	2578
6.	Maximum temperature of cladding outer surface	K	-	1214	1261
7.	Cladding burst	Failed, Unfailed	Failed	Failed	Failed
8.	Cladding residual hoop strain**				
	- average	%	8.94	6.12	5.45
	- maximum	%	18.90	9.09	5.45

\* Average value of peak fuel enthalpy 164.2 cal/g fuel

\*\* Average value along the fuel stack length



***Appendix E-11***  
***Individual Characteristics of Fuel Rod # RT11***  
***after the BGR Test***

# RT11

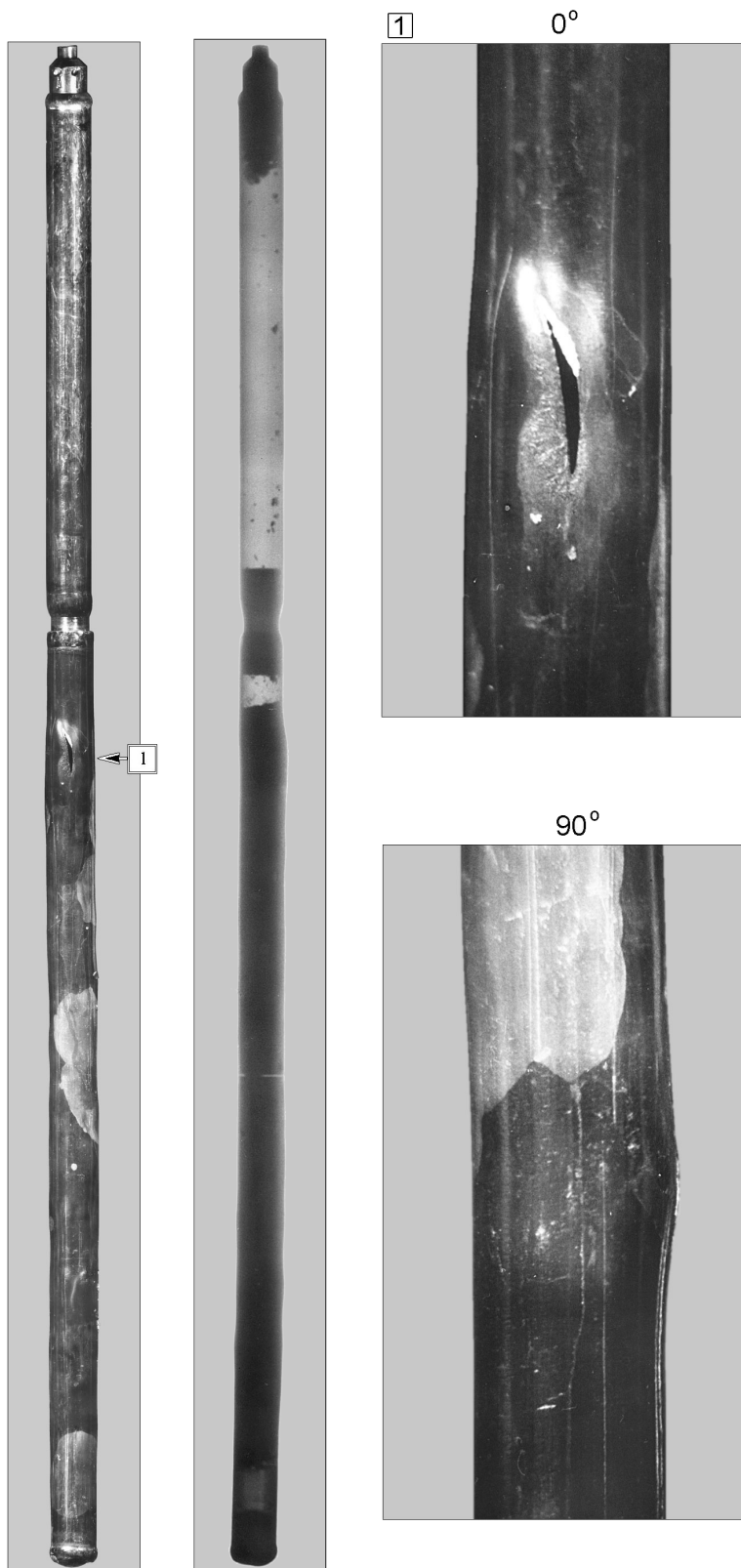


Fig.E-11.1. Appearance of failed fuel rod # RT11 after the BGR test (photographs and X-ray photograph)

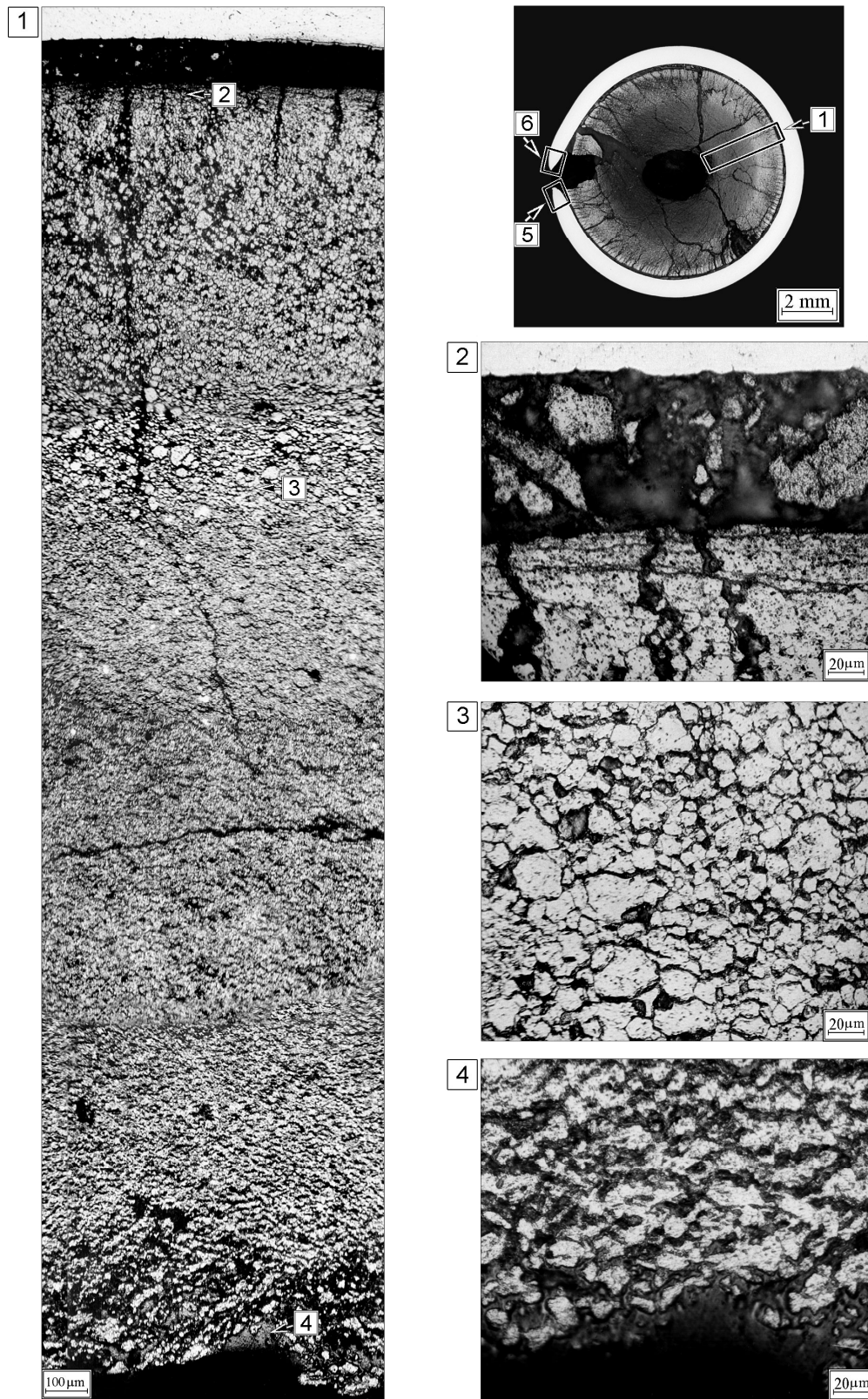
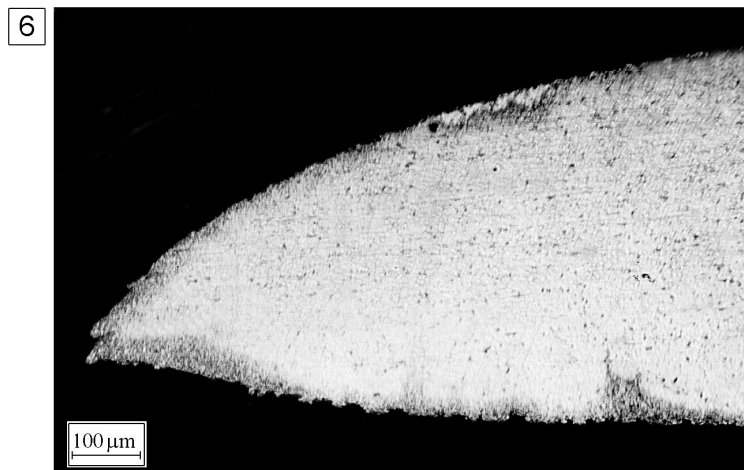
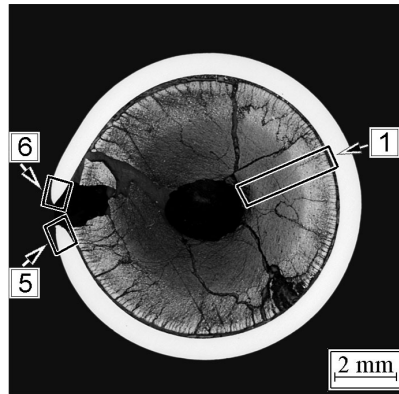
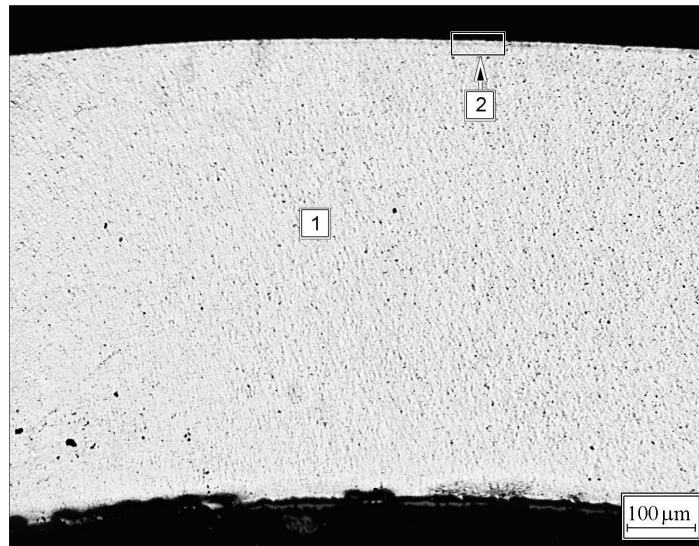


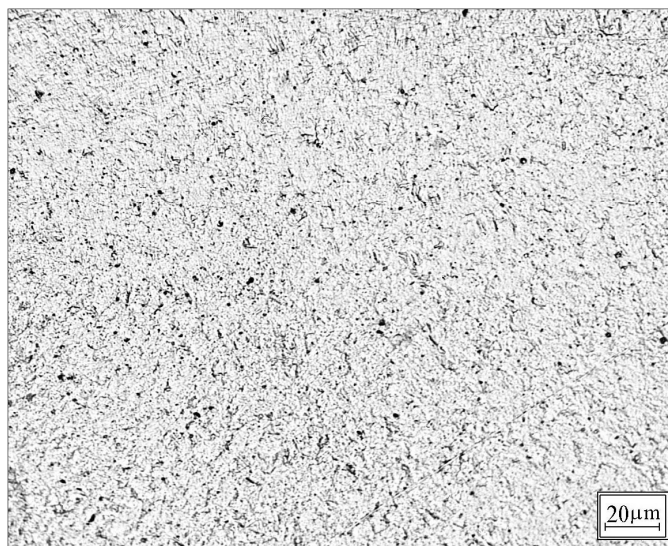
Fig.E-11.2. Cross-section and fuel microstructure of fuel rod # RT11 at 157 mm elevation (from low cap)



**Fig.E-11.3. Cross-section and cladding microstructure of fuel rod # RT11 in the burst area at 157 mm elevation (from low cap)**



1



2

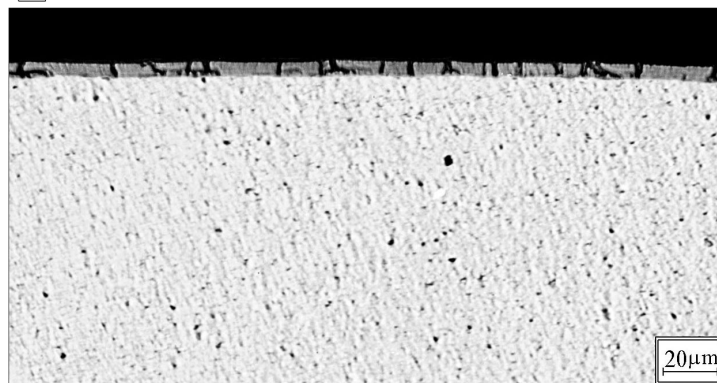


Fig.E-11.4. Cladding microstructure of fuel rod # RT11 at 157 mm elevation (from low cap)

# # RT11

**Table E-11.1. Time dependent energy characteristics of fuel rod # RT11**

Time (s)	Relative reactor power (current/ maximum value) (per-unit)	Cumulative number of fissions in fuel rod (fiss) x 10 <sup>-14</sup>	Power of fuel rod <sup>1)2)</sup> (kW)	Energy deposition		Fuel enthalpy <sup>3)</sup>	
				(cal/g fuel)	(J/g fuel)	FRAP-T6	RAPTA-5
0.000	0.00E+00	0.000	0.000	0.000	0.000	0.000	0.000
0.001	2.61E-03	0.039	22.11	0.042	0.177	0.671	0.041
0.002	1.16E-02	0.217	98.28	0.235	0.983	0.671	0.226
0.003	5.28E-02	1.024	447.3	1.108	4.637	1.345	1.121
0.004	2.29E-01	4.652	1942	5.023	21.03	5.256	5.196
0.005	6.89E-01	17.65	5836	19.04	79.72	18.922	19.396
0.006	9.93E-01	44.50	8414	48.02	201.1	46.962	48.187
0.007	6.32E-01	69.48	5352	75.04	314.2	73.074	74.807
0.008	2.89E-01	82.68	2451	89.26	373.7	86.708	88.540
0.009	1.38E-01	88.68	1171	95.76	400.9	92.802	94.659
0.010	8.17E-02	91.83	692.7	99.15	415.1	96.005	97.592
0.012	5.36E-02	95.59	453.8	103.3	432.3	99.478	100.921
0.014	5.43E-02	98.76	460.0	106.6	446.5	102.185	103.704
0.016	6.37E-02	102.2	539.7	110.4	462.2	105.277	106.937
0.018	7.36E-02	106.3	623.5	114.9	480.9	109.043	110.867
0.020	7.85E-02	111.1	665.4	119.8	501.5	113.303	115.318
0.022	7.36E-02	115.3	623.5	124.7	522.1	117.572	119.748
0.024	6.17E-02	119.3	522.9	129.1	540.5	121.301	123.610
0.026	4.96E-02	123.0	420.3	132.7	555.4	124.284	126.707
0.028	4.02E-02	125.6	340.6	135.5	567.5	126.612	129.092
0.030	3.43E-02	127.8	290.4	137.9	577.4	128.479	131.024
0.050	2.75E-02	144.9	232.9	156.4	654.7	143.008	145.560
0.070	2.46E-02	160.1	208.8	173.1	724.6	154.413	158.770
0.090	2.16E-02	173.6	183.2	187.5	784.9	167.473	169.947
0.110	1.72E-02	185.5	146.1	200.2	838.2	178.630	179.596
0.130	8.76E-03	193.3	74.46	208.7	873.6	185.748	185.120
0.150	3.37E-03	196.7	28.83	212.2	888.5	188.096	186.670
0.200	7.24E-04	198.9	6.354	214.9	899.6	187.774	185.441
1.000	7.72E-05	202.2	0.801	218.9	916.6	164.951	170.085
10.00	8.95E-06	208.6	0.106	228.3	956.0	51.589	73.945
100.0	1.80E-07	212.3	0.004	234.4	981.2	5.968	11.422
1000	7.08E-13	212.4	1.89E-04	236.5	990.0	0.000	0.000

<sup>1)</sup> Average values determined in accordance with results of RRC KI and VNIIEF calculations

<sup>2)</sup> Maximum power value is 8470 kW (t=0.00588 s)

<sup>3)</sup> Average radial value

**Table E-11.2. Radial energy characteristics of fuel rod # RT11\***

Parameters	Coordinates of fuel radial layers (mm)			
	1 layer (1.250-2.834)	2 layer (2.834-3.452)	3 layer (3.452-3.722)	4 layer (3.722-3.808)
Number of fissions $\times 10^{-14}$ (fiss)	9.593	6.117	3.707	1.824
Fission density $\times 10^{-13}$ (fiss/g fuel)	3.050	3.239	3.937	5.793
Power** (kW)	3818	2438	1482	732.3
Energy deposition (cal/g fuel)	213.2	226.7	276.2	408.0
Energy deposition (J/g fuel)	892.7	949.0	1157	1708
Energy deposition*** (per-unit)	0.523	0.556	0.677	1.000

\* Average values were determined in accordance with results of RRC KI and VNIIEF calculations

\*\* The power for the entire length of each layer at time 0.00588 s

\*\*\* Energy deposition in current layer/energy deposition in 4<sup>th</sup> layer

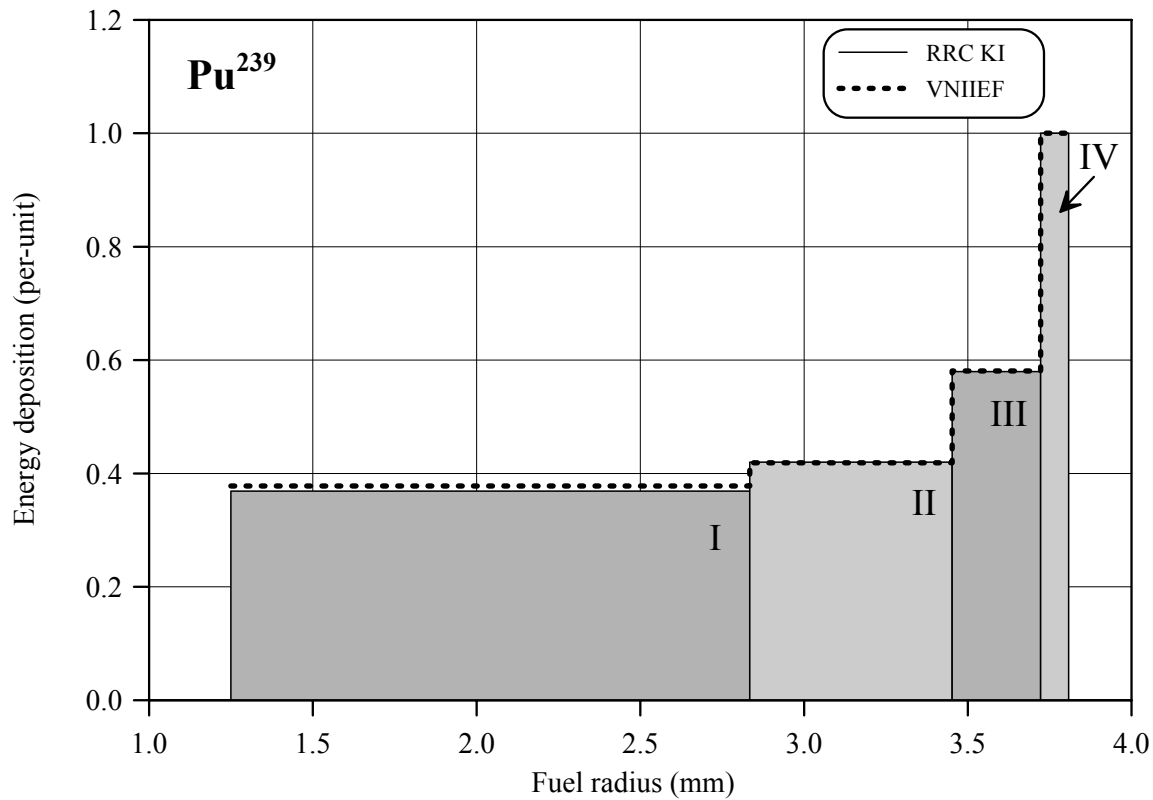
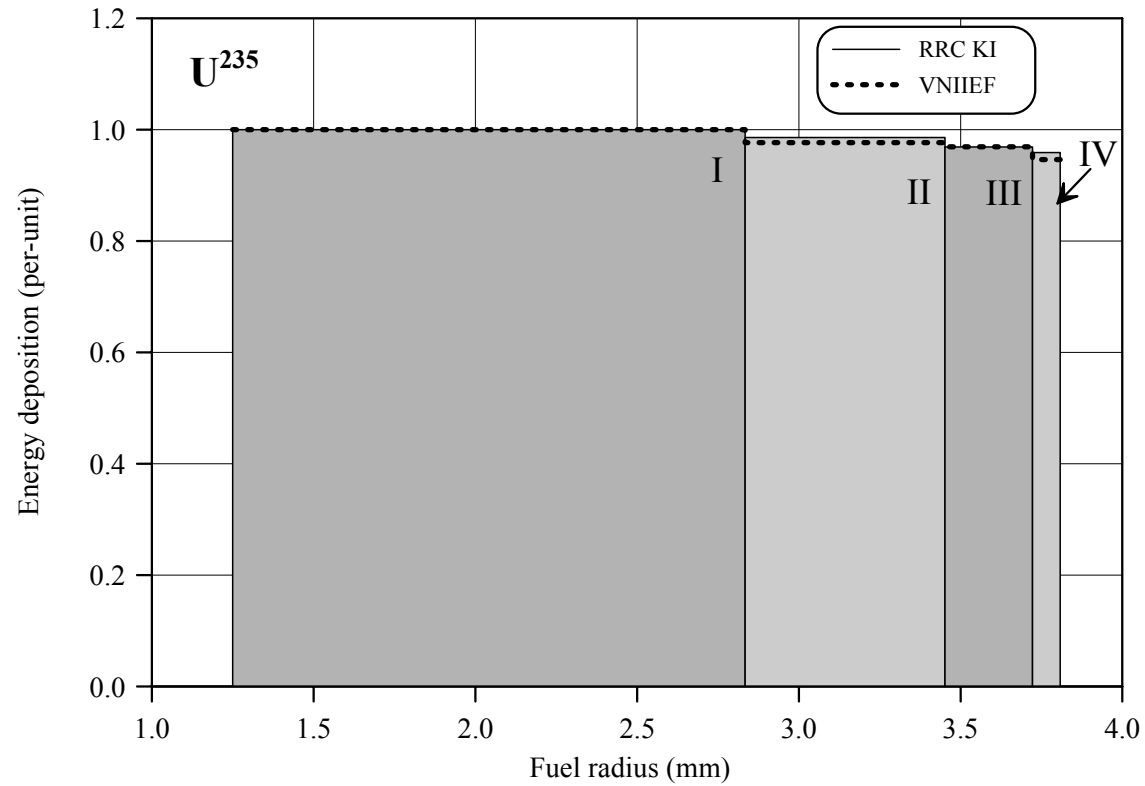
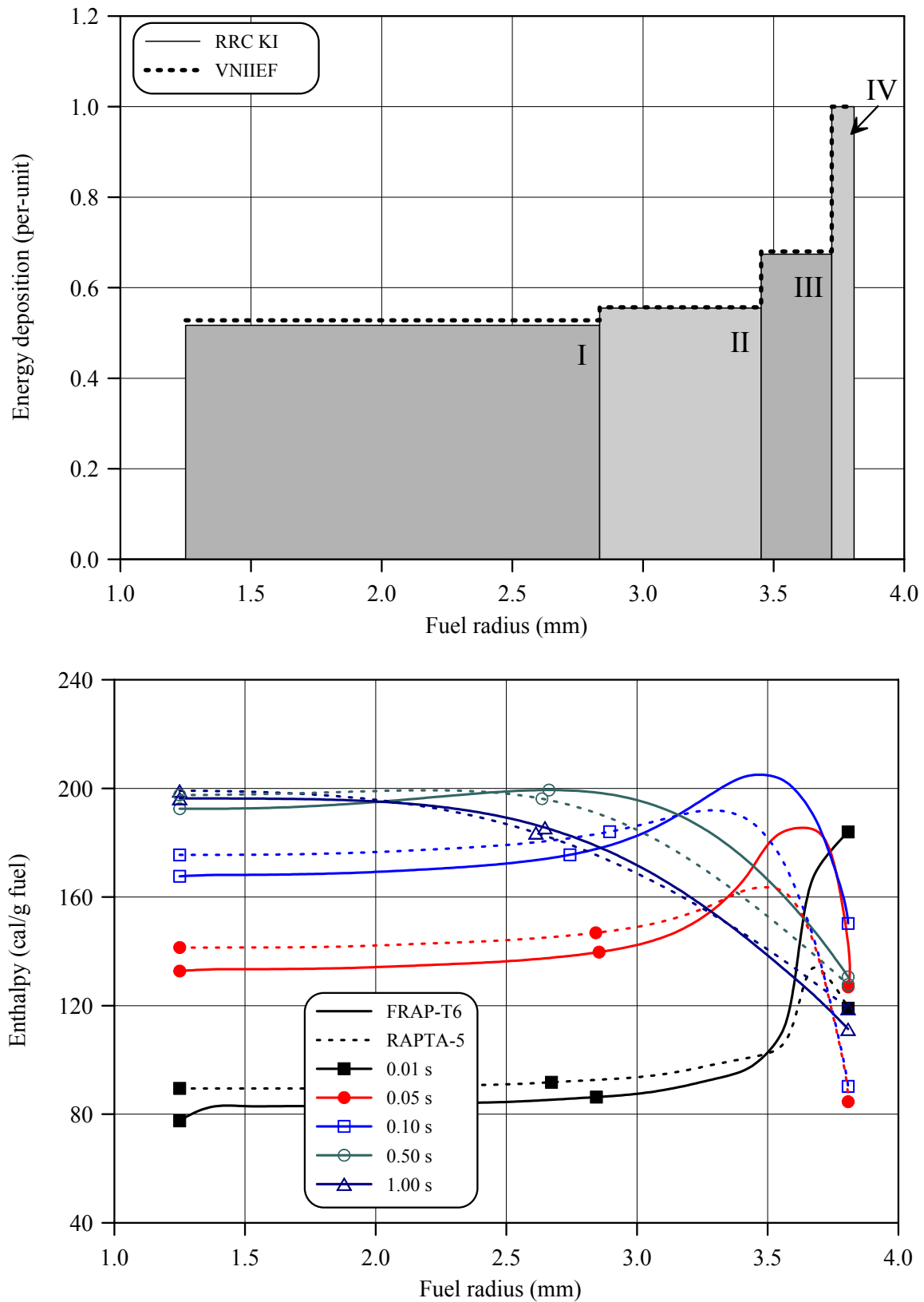
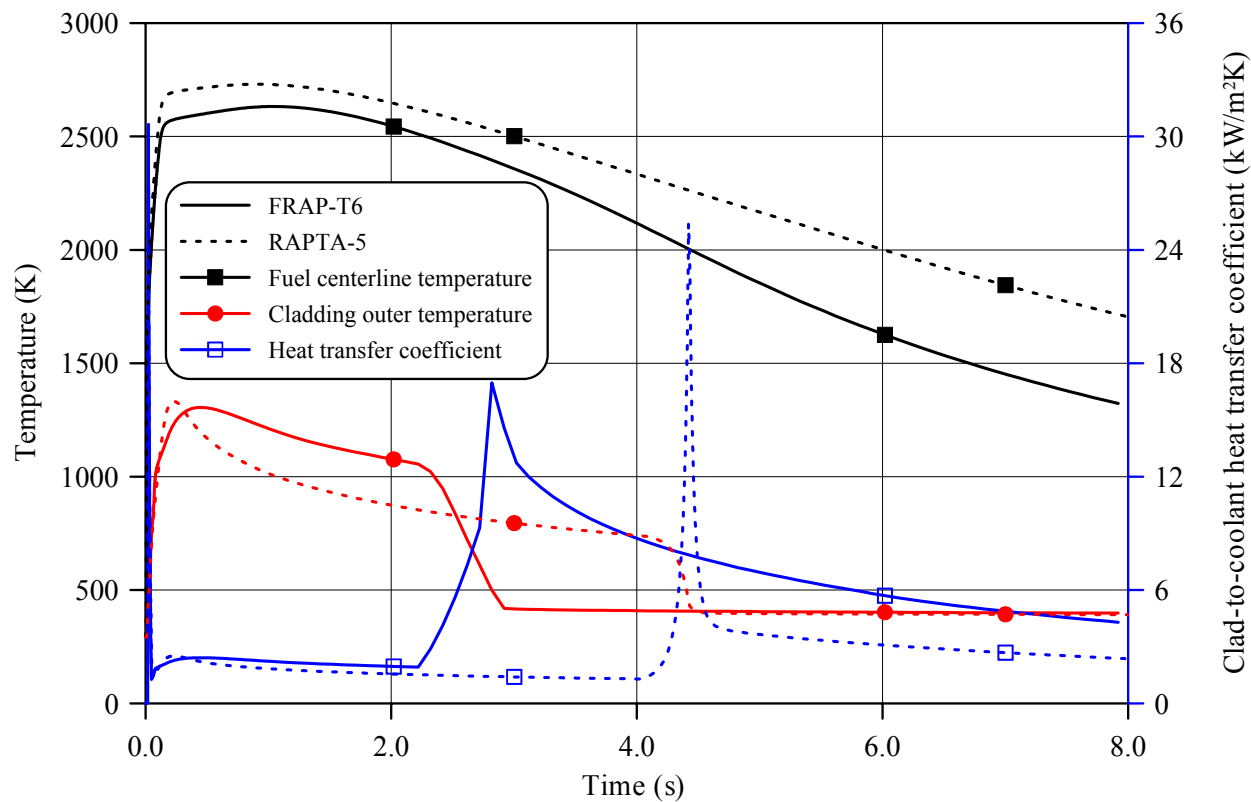
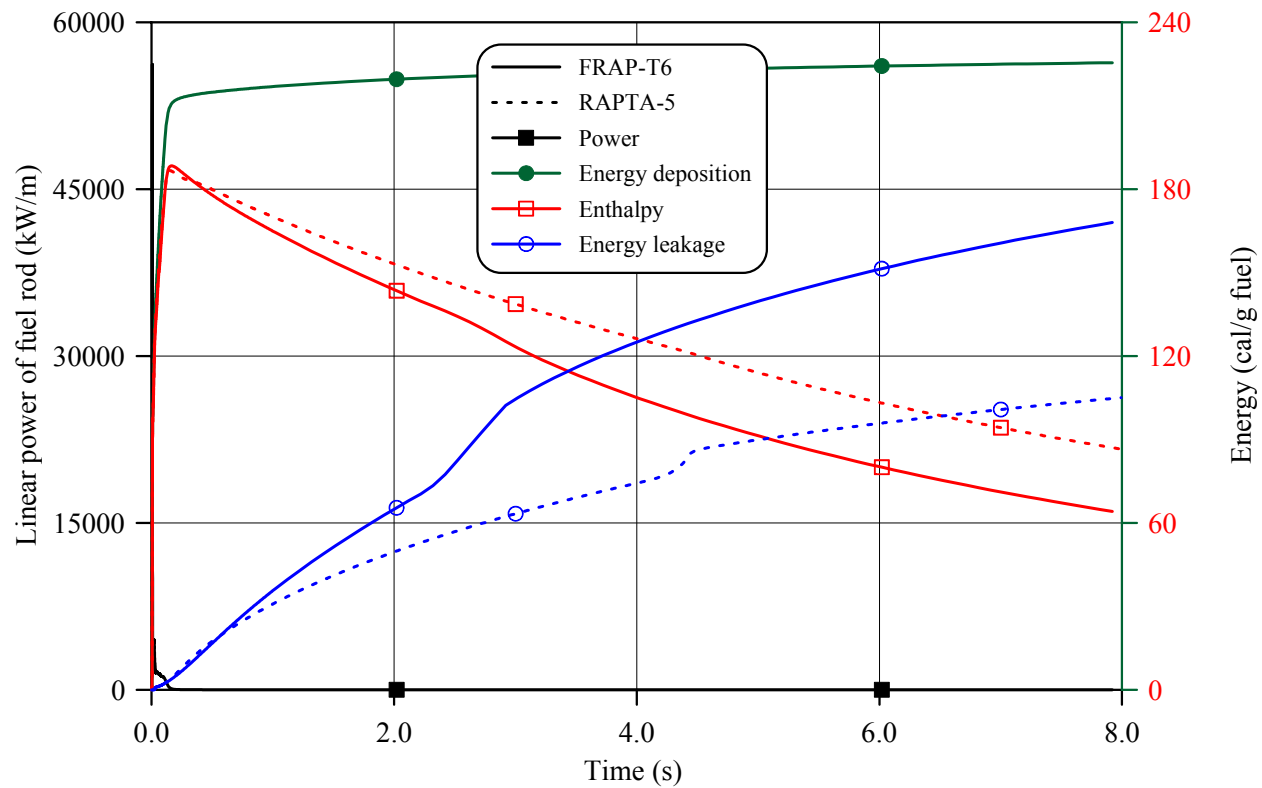


Fig.E-11.5.  $U^{235}$  and  $Pu^{239}$  radial distribution of energy deposition for fuel rod # RT11



**Fig.E-11.6. Radial distribution of energy deposition and fuel enthalpy for fuel rod # RT11**

# # RT11



**Fig.E-11.7. Thermal history of fuel rod # RT11 during the B1GR test in accordance with FRAP-T6/VVER and RAPTA-5 calculations**

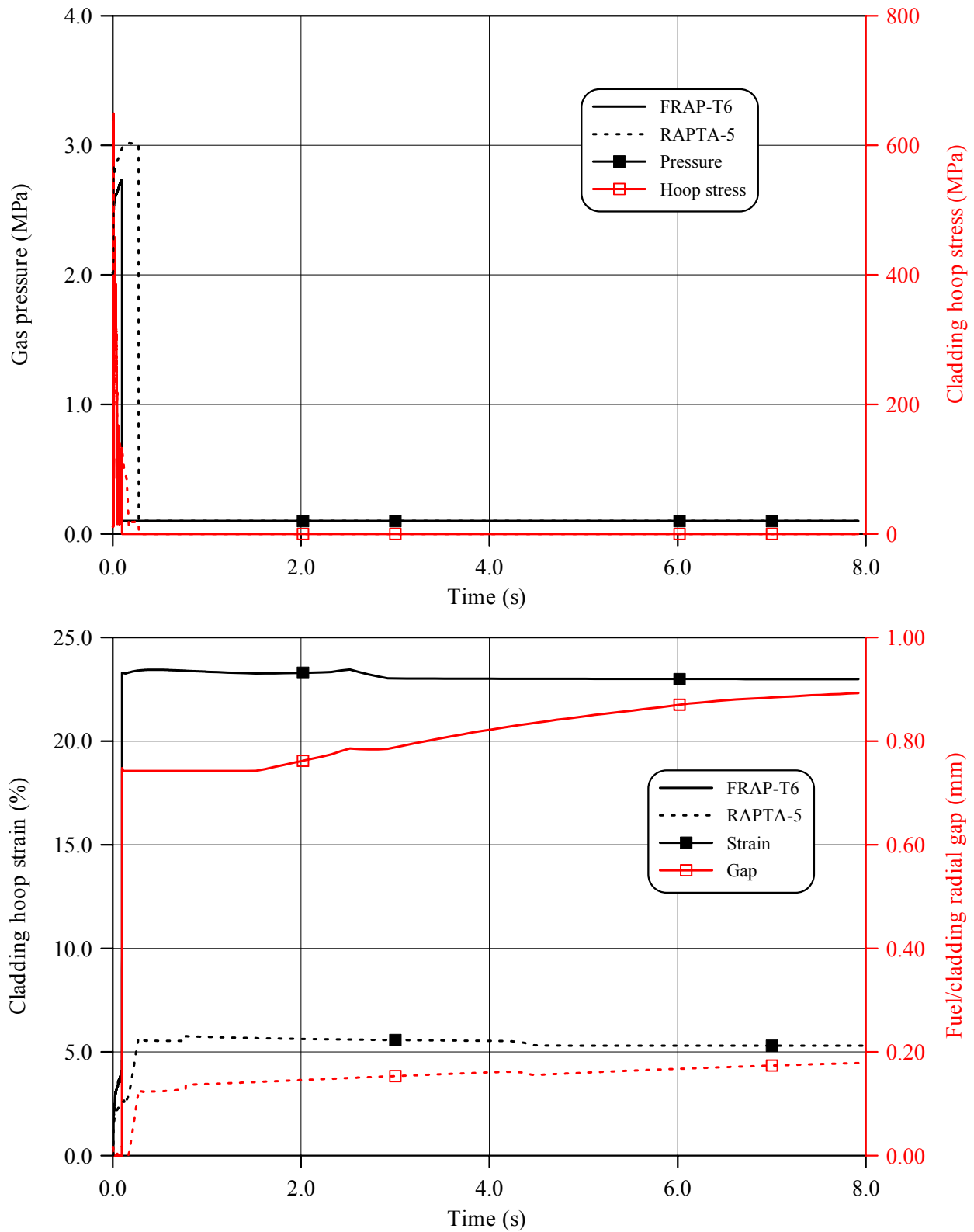
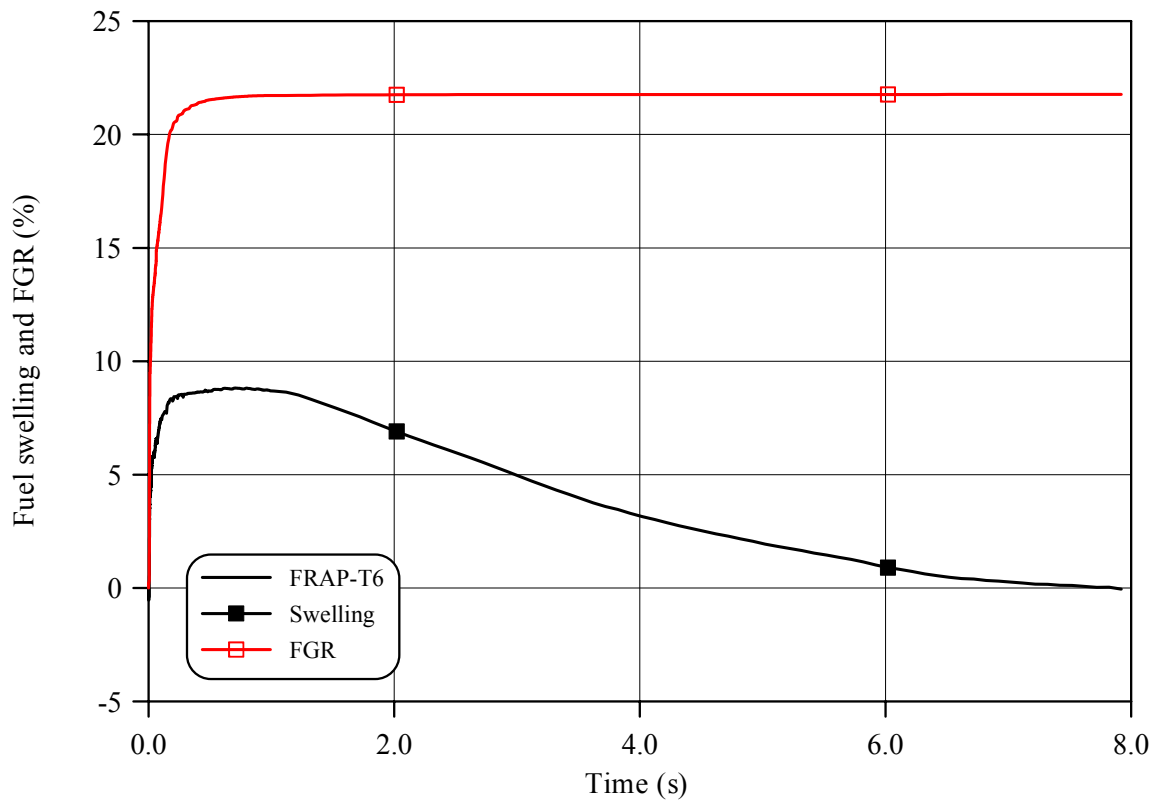
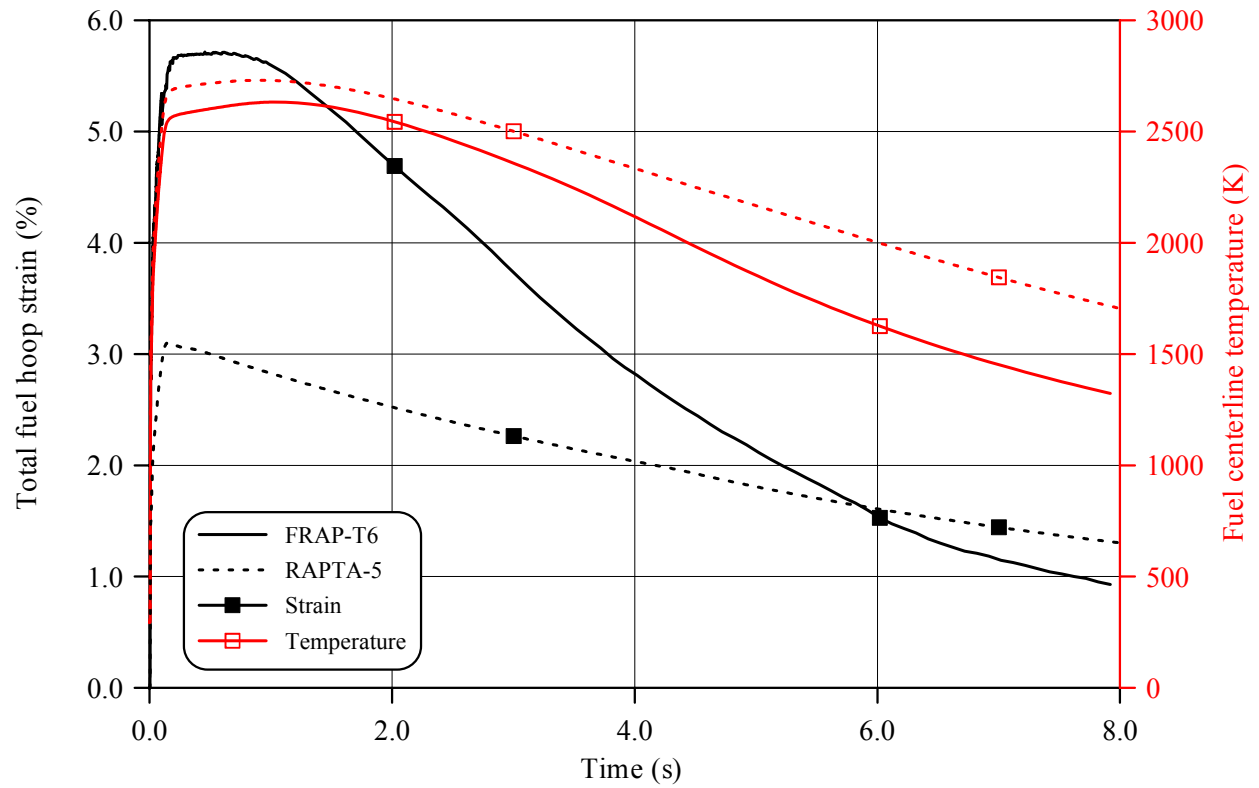


Fig.E-11.8. Mechanical behavior of fuel rod # RT11 during the BGR test in accordance with FRAP-T6/VVER and RAPTA-5 calculations

# # RT11

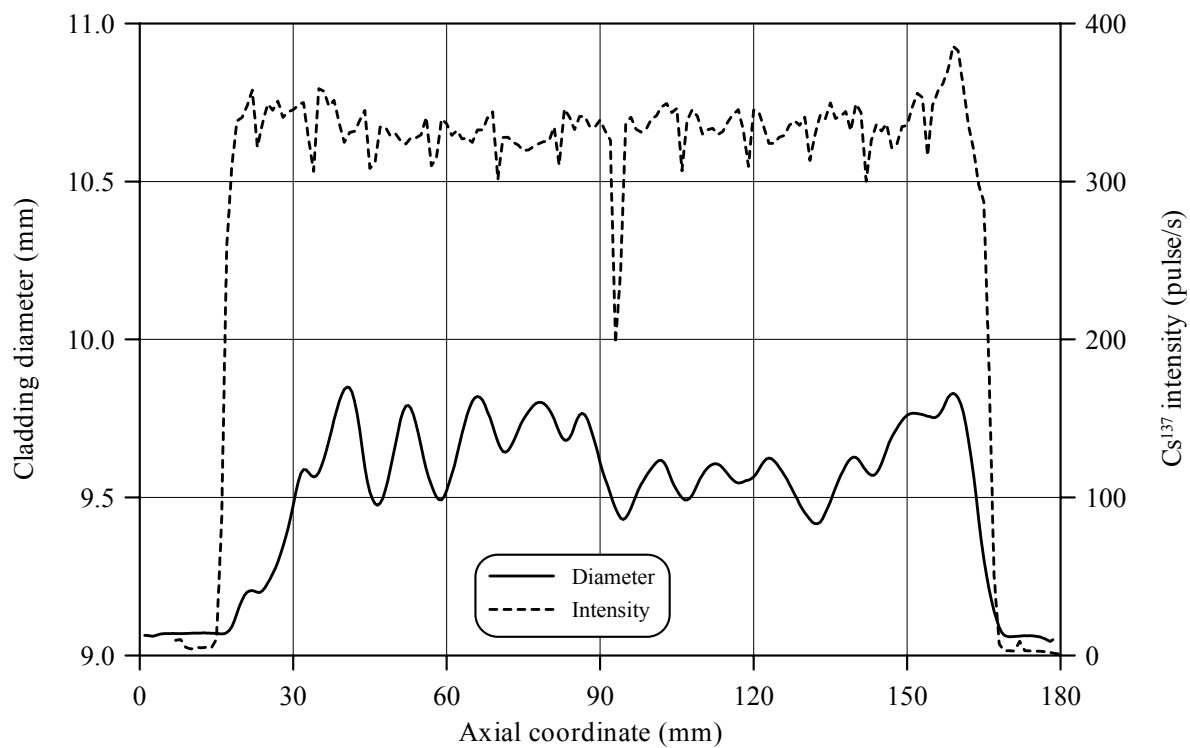


**Fig.E-11.9. Fuel behavior during the B1GR test of fuel rod # RT11 in accordance with FRAP-T6/VVER and RAPTA-5 calculations**

**Table E-11.3. Axial distribution of cladding average outer diameter in fuel rod # RT11\***

Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)
25	9.229	63	9.702	101	9.611	139	9.623
27	9.296	65	9.804	103	9.597	141	9.609
29	9.404	67	9.808	105	9.522	143	9.571
31	9.550	69	9.727	107	9.492	145	9.607
33	9.579	71	9.646	109	9.541	147	9.691
35	9.579	73	9.676	111	9.594	149	9.743
37	9.681	75	9.747	113	9.606	151	9.766
39	9.804	77	9.791	115	9.573	153	9.762
41	9.847	79	9.797	117	9.546	155	9.753
43	9.713	81	9.749	119	9.555	157	9.781
45	9.518	83	9.681	121	9.587	159	9.830
47	9.481	85	9.727	123	9.625	161	9.769
49	9.591	87	9.762	125	9.596	163	9.568
51	9.747	89	9.672	127	9.543	165	9.304
53	9.783	91	9.558	129	9.479	167	9.141
55	9.661	93	9.466	131	9.430	169	9.064
57	9.539	95	9.435	133	9.422	171	9.060
59	9.493	97	9.505	135	9.488	173	9.063
61	9.573	99	9.568	137	9.569	175	9.062

\* Measured value determined on the basis of profilometry data (16 azimuthal directions)

**Fig.E-11.10. Cladding measured average diameter and  $\gamma$ -scanning results for fuel rod # RT11**

# # RT11

**Table E-11.4. The PIE results for fuel rod # RT11**

Parameter		Value
1.	Cladding outer diameter (mm):	
1.1.	Maximum diameter of the bidimensional data sample in "fuel rod length - azimuthal angle" coordinates (mm)	10.02
1.2.	Averaged azimuthal diameter and maximum diameter along the length selected from the sample of averaged azimuthal diameter (mm)	9.85
1.3.	Averaged diameter of the bidimensional data sample in "fuel rod length - azimuthal angle" coordinates (mm)	9.58
2.	Cladding maximum residual hoop strain (%)	8.20
3.	Fuel pellet conditional diameter (mm) in cross-section*: at 157 mm elevation	8.31
4.	ZrO <sub>2</sub> outer thickness (μm) in cross-section: at 157 mm elevation	4
5.	ZrO <sub>2</sub> inner thickness (μm) in cross-section: at 157 mm elevation	0
6.	Parameters characterizing FGR:	
6.1.	Gas composition (% by volume):	
	He	-
	N <sub>2</sub>	-
	O <sub>2</sub>	-
	Ar	-
	CO <sub>2</sub>	-
	Kr	-
	Xe	-
6.2.	Free gas volume (cm <sup>3</sup> )	-
6.3.	Gas volume under normal conditions (cm <sup>3</sup> )	-
6.4.	Gas pressure under normal conditions (MPa)	-

\* Reference value determined by the processing of fuel cross-section photographs

**Table E-11.5. Organized BGR test results for fuel rod # RT11**

Parameter	Unit	Value			
		Measured	Calculated		
			FRAP-T6	RAPTA-5	
1. Fuel burnup	MW d/kg U	47.2	47.2	47.2	
2. Initial gas pressure	MPa	2.0	2.0	2.0	
3. Energy deposition	cal/g fuel	236.5	236.5	236.5	
4. Peak fuel enthalpy*	cal/g fuel	-	188.4	186.7	
5. Fuel maximum temperature	K	-	2782	2774	
6. Maximum temperature of cladding outer surface	K	-	1306	1333	
7. Cladding burst	Failed, Unfailed	Failed	Failed	Failed	
8. Cladding residual hoop strain**					
- average	%	5.45	3.68	5.76	
- maximum	%	8.20	22.90	5.76	

\* Average value of peak fuel enthalpy 187.5 cal/g fuel

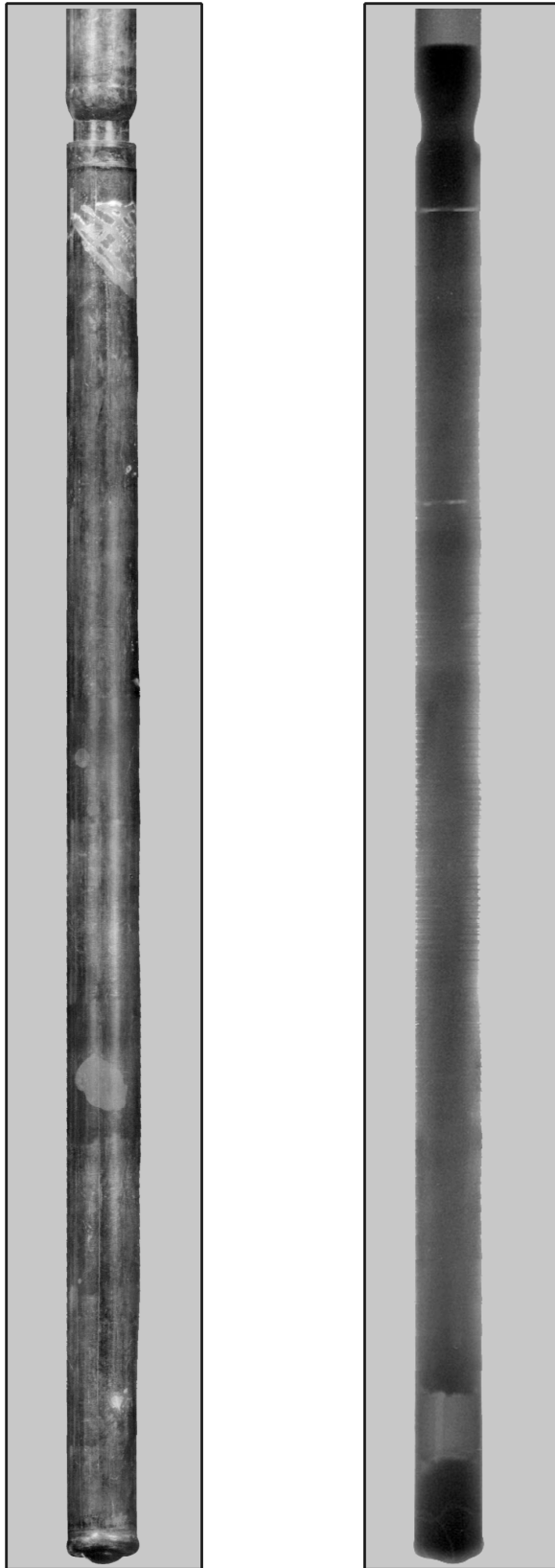
\*\* Average value along the fuel stack length





***Appendix E-12***  
***Individual Characteristics of Fuel Rod # RT12***  
***after the BGR Test***

**# RT12**



**Fig.E-12.1. Appearance of unfailed fuel rod # RT12 after the BGR test (photographs and X-ray photograph)**

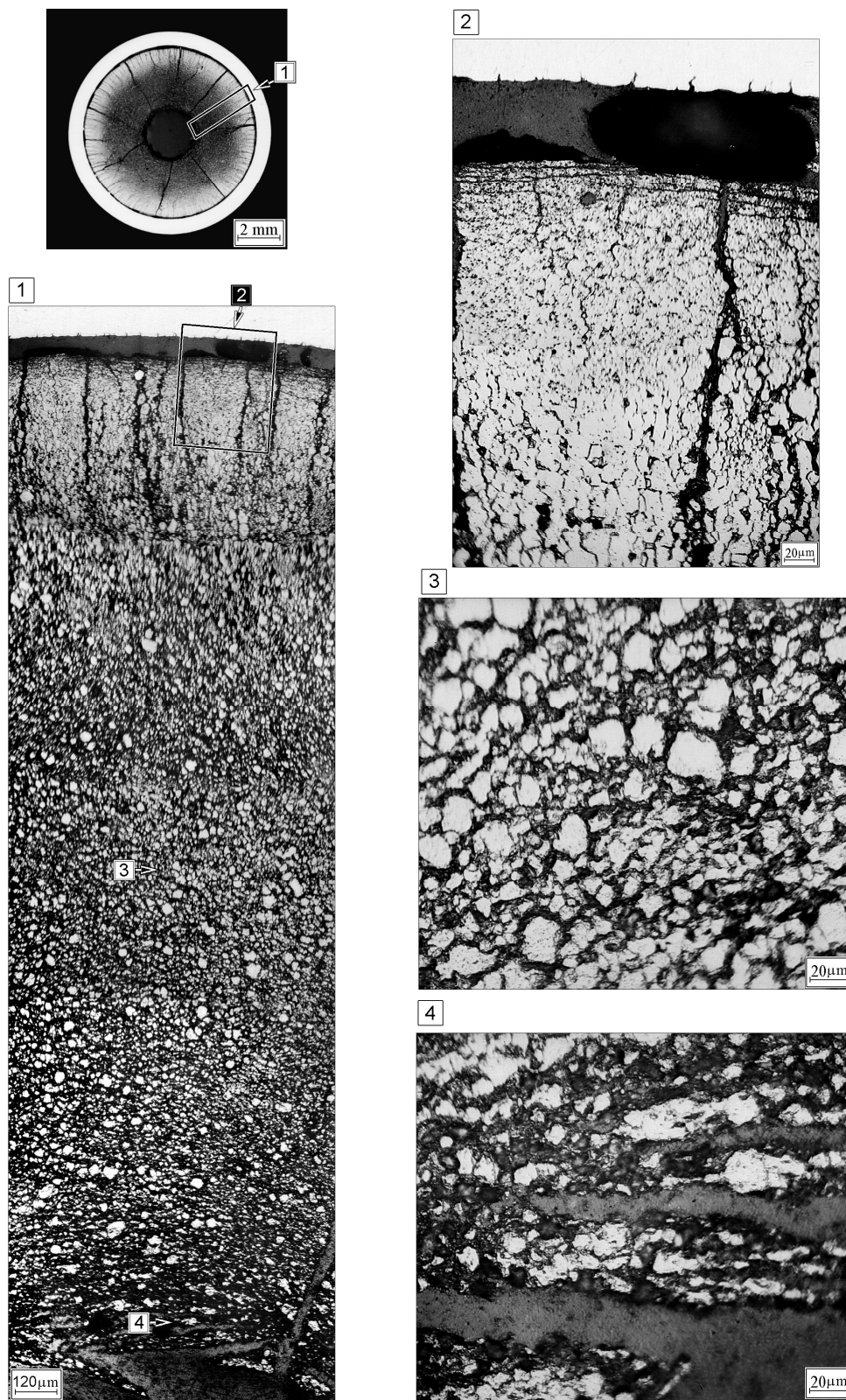
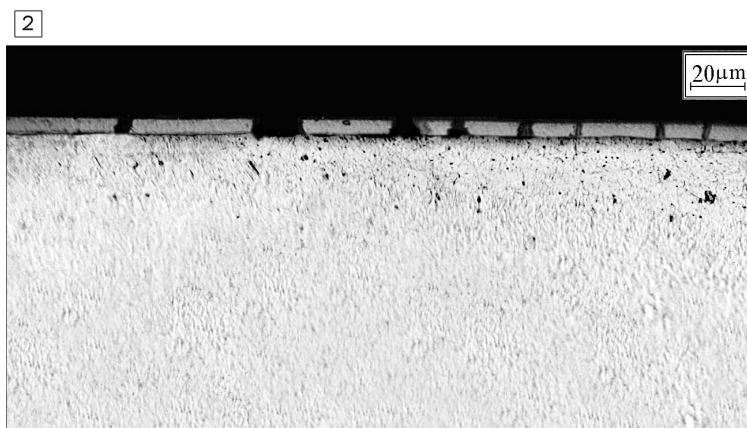
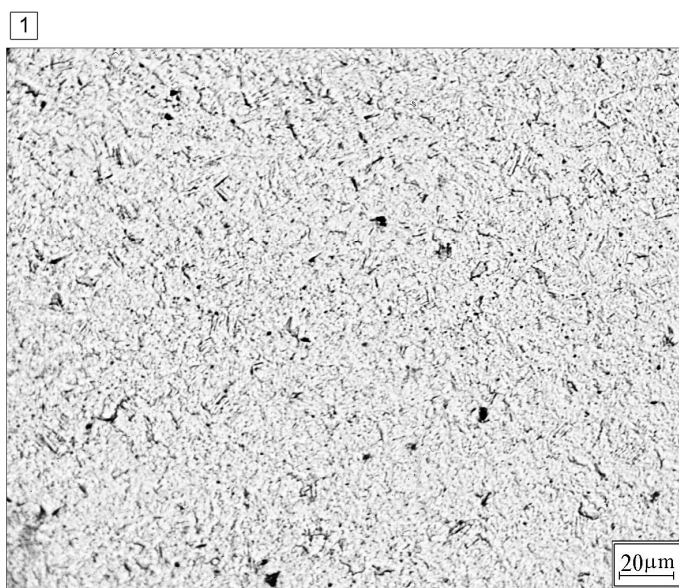
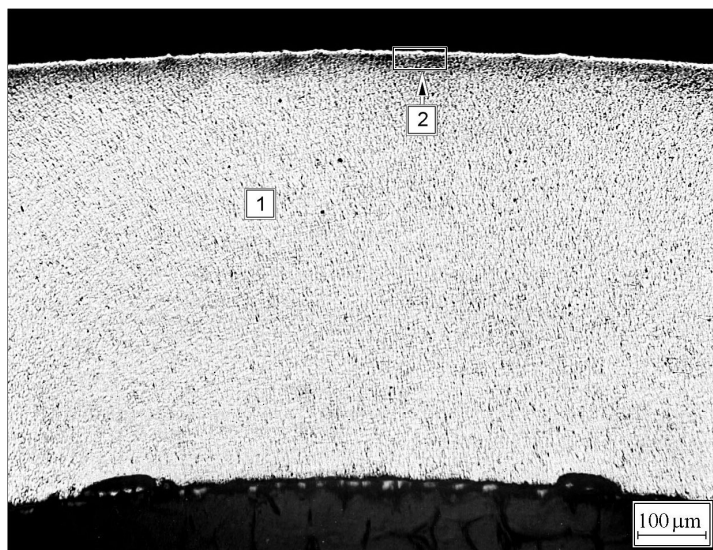


Fig.E-12.2. Cross-section and fuel microstructure of fuel rod # RT12 at 54 mm elevation (from low cap)



**Fig.E-12.3. Cladding microstructure of fuel rod # RT12 at 54 mm elevation (from low cap)**

Table E-12.1. Time dependent energy characteristics of fuel rod # RT12

Time (s)	Relative reactor power (current/ maximum value) (per-unit)	Cumulative number of fissions in fuel rod (fiss) x10 <sup>-14</sup>	Power of fuel rod <sup>1)2)</sup> (kW)	Energy deposition		Fuel enthalpy <sup>3)</sup>	
				(cal/g fuel)	(J/g fuel)	FRAP-T6	RAPTA-5
0.000	0.00E+00	0.000	0.000	0.000	0.000	0.000	0.000
0.001	2.98E-03	0.039	21.69	0.042	0.177	0.671	0.010
0.002	1.23E-02	0.208	89.58	0.225	0.941	0.671	0.048
0.003	4.92E-02	0.882	357.9	0.951	3.983	0.671	0.221
0.004	1.95E-01	3.617	1420	3.901	16.33	1.238	0.983
0.005	6.03E-01	13.21	4386	14.24	59.60	4.254	3.962
0.006	9.97E-01	34.62	7246	37.34	156.3	14.601	14.236
0.007	7.64E-01	58.23	5558	62.78	262.8	36.948	36.820
0.008	3.89E-01	72.66	2829	78.35	328.0	61.565	61.560
0.009	1.92E-01	79.71	1397	85.97	359.9	76.845	76.530
0.010	1.09E-01	83.35	791.2	89.94	376.6	84.231	83.649
0.012	6.29E-02	87.45	457.6	94.31	394.8	90.308	89.170
0.014	5.87E-02	90.53	426.7	97.58	408.6	93.524	92.025
0.016	6.41E-02	93.60	466.8	101.0	422.7	96.353	94.690
0.018	6.96E-02	97.03	506.3	104.7	438.2	99.400	97.679
0.020	6.95E-02	100.6	505.4	108.5	454.3	102.696	100.975
0.022	6.41E-02	104.0	466.1	112.2	469.8	106.008	104.271
0.024	5.57E-02	107.1	405.1	115.5	483.6	109.043	107.294
0.026	4.72E-02	109.9	342.9	118.4	495.6	111.652	109.884
0.028	3.99E-02	112.0	290.2	120.8	505.6	113.817	112.022
0.030	3.49E-02	114.0	253.8	122.8	514.1	115.607	113.796
0.050	3.13E-02	130.1	227.8	140.2	587.1	126.792	127.562
0.070	2.54E-02	144.4	184.9	155.7	652.0	138.170	139.931
0.090	1.83E-02	155.5	133.2	167.8	702.6	146.854	149.141
0.110	8.26E-03	162.4	60.22	175.1	732.9	152.608	153.953
0.130	3.11E-03	165.0	22.83	177.8	744.6	154.473	154.893
0.150	1.52E-03	166.0	11.21	179.1	749.8	154.714	154.282
0.200	4.74E-04	167.1	3.632	180.3	754.7	153.881	151.725
1.000	7.48E-05	169.6	0.667	183.4	767.8	135.980	128.738
10.00	8.71E-06	175.4	0.089	191.3	800.7	60.607	30.472
100.0	1.76E-07	177.8	0.003	196.3	821.7	10.376	5.051
1000	6.91E-13	177.9	1.59E-04	198.1	829.2	0.000	0.000

<sup>1)</sup> Average values determined in accordance with results of RRC KI and VNIIEF calculations<sup>2)</sup> Maximum power value is 7270.5 kW (t=0.00606 s)<sup>3)</sup> Average radial value

# # RT12

**Table E-12.2. Radial energy characteristics of fuel rod # RT12\***

Parameters	Coordinates of fuel radial layers (mm)			
	1 layer (1.250-2.834)	2 layer (2.834-3.452)	3 layer (3.452-3.722)	4 layer (3.722-3.808)
Number of fissions $\times 10^{-14}$ (fiss)	7.961	5.152	3.130	1.569
Fission density $\times 10^{-13}$ (fiss/g fuel)	2.528	2.723	3.318	4.974
Power ** (kW)	3243	2102	1281	644.7
Energy deposition (cal/g fuel)	176.7	190.7	233.0	350.4
Energy deposition (J/g fuel)	740.0	798.3	975.4	1467
Energy deposition *** (per-unit)	0.505	0.544	0.665	1.000

\* Average values were determined in accordance with results of RRC KI and VNIIEF calculations

\*\* The power for the entire length of each layer at time 0.00606 s

\*\*\* Energy deposition in current layer/energy deposition in 4<sup>th</sup> layer

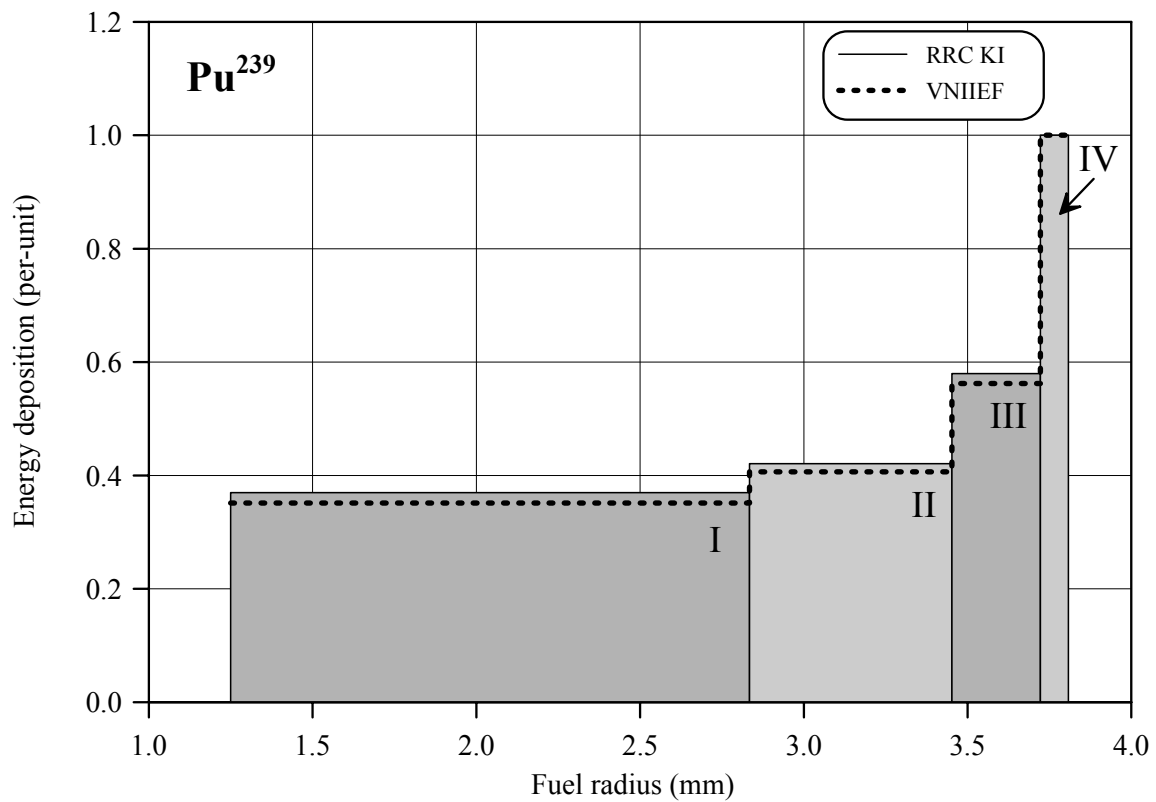
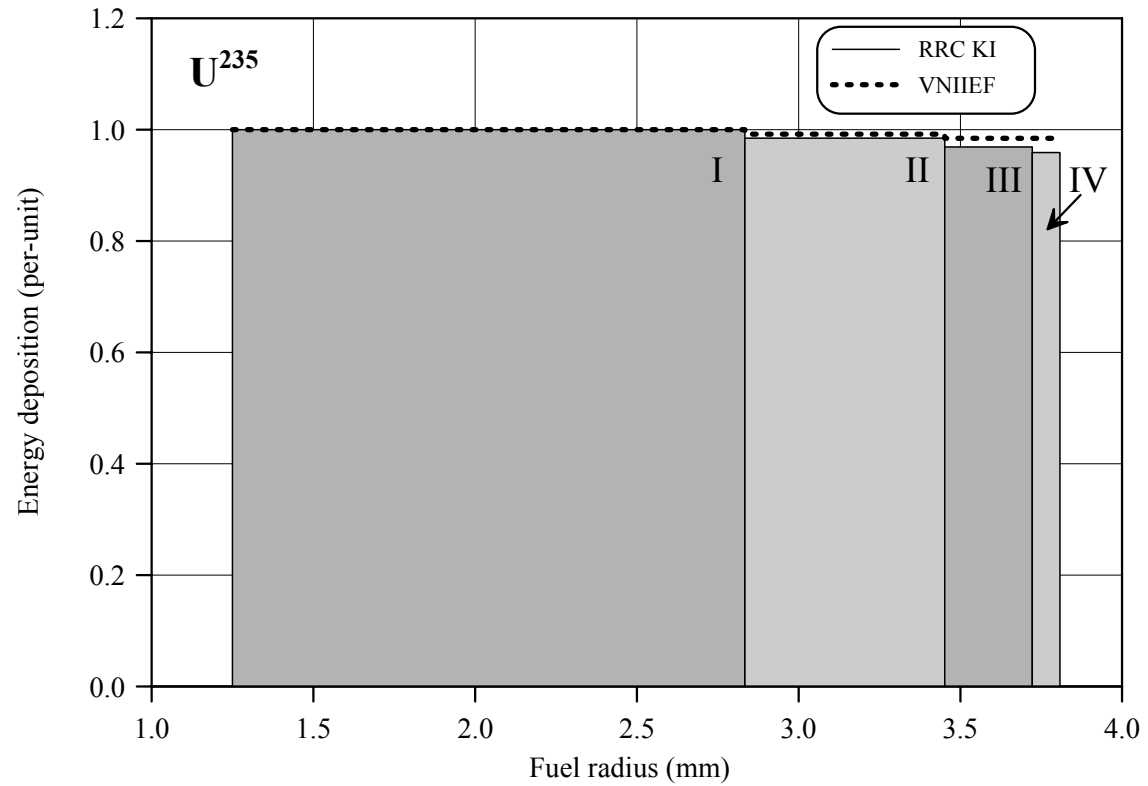


Fig.E-12.4.  $U^{235}$  and  $Pu^{239}$  radial distribution of energy deposition for fuel rod # RT12

# # RT12

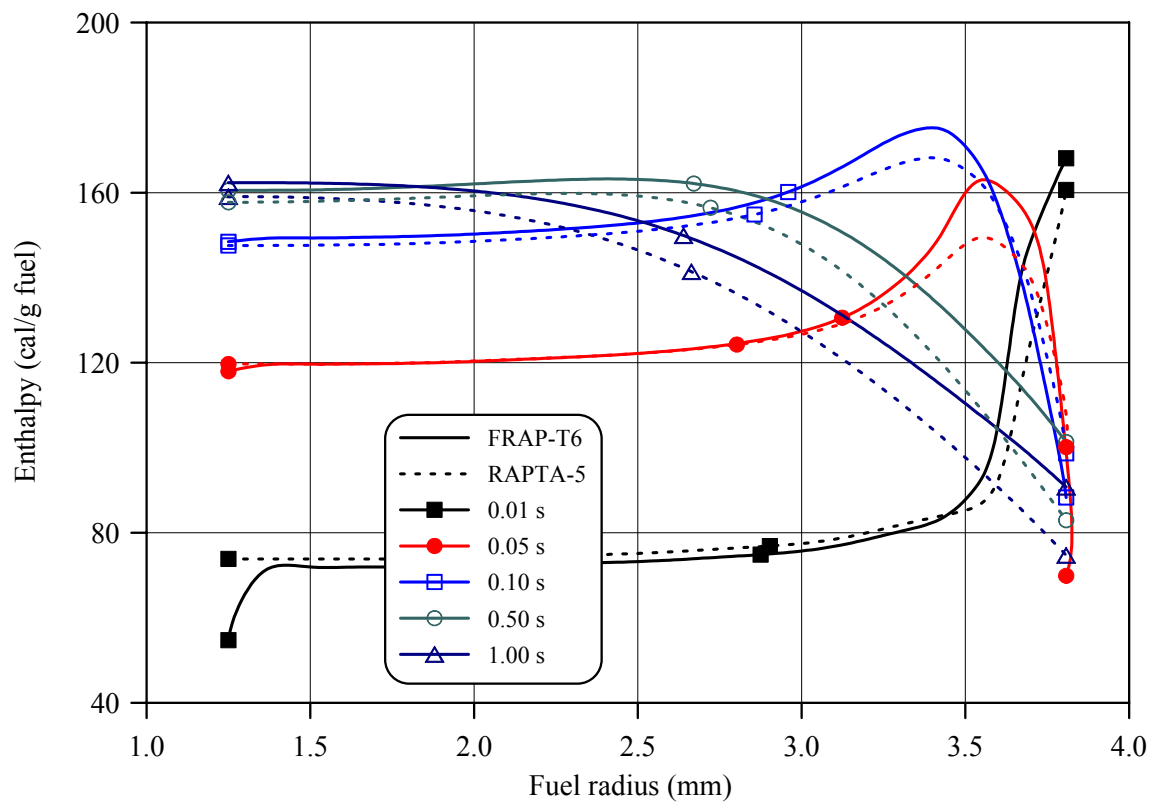
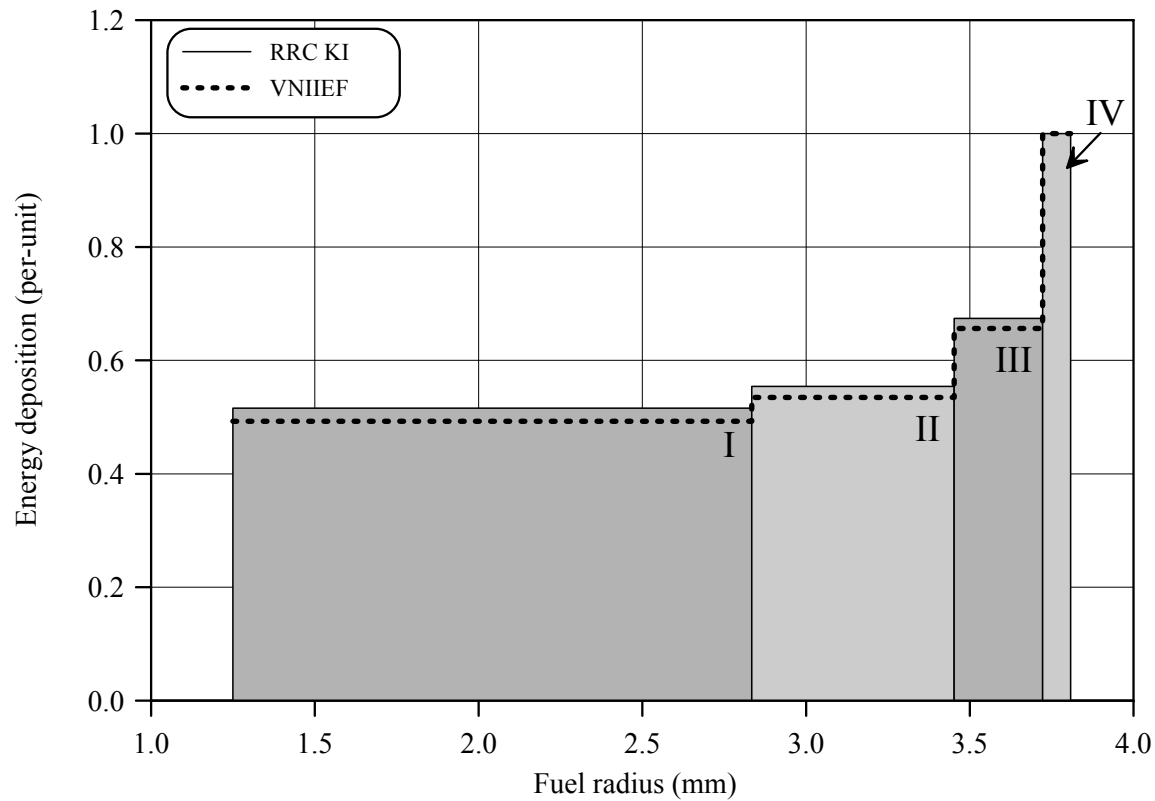


Fig.E-12.5. Radial distribution of energy deposition and fuel enthalpy for fuel rod # RT12



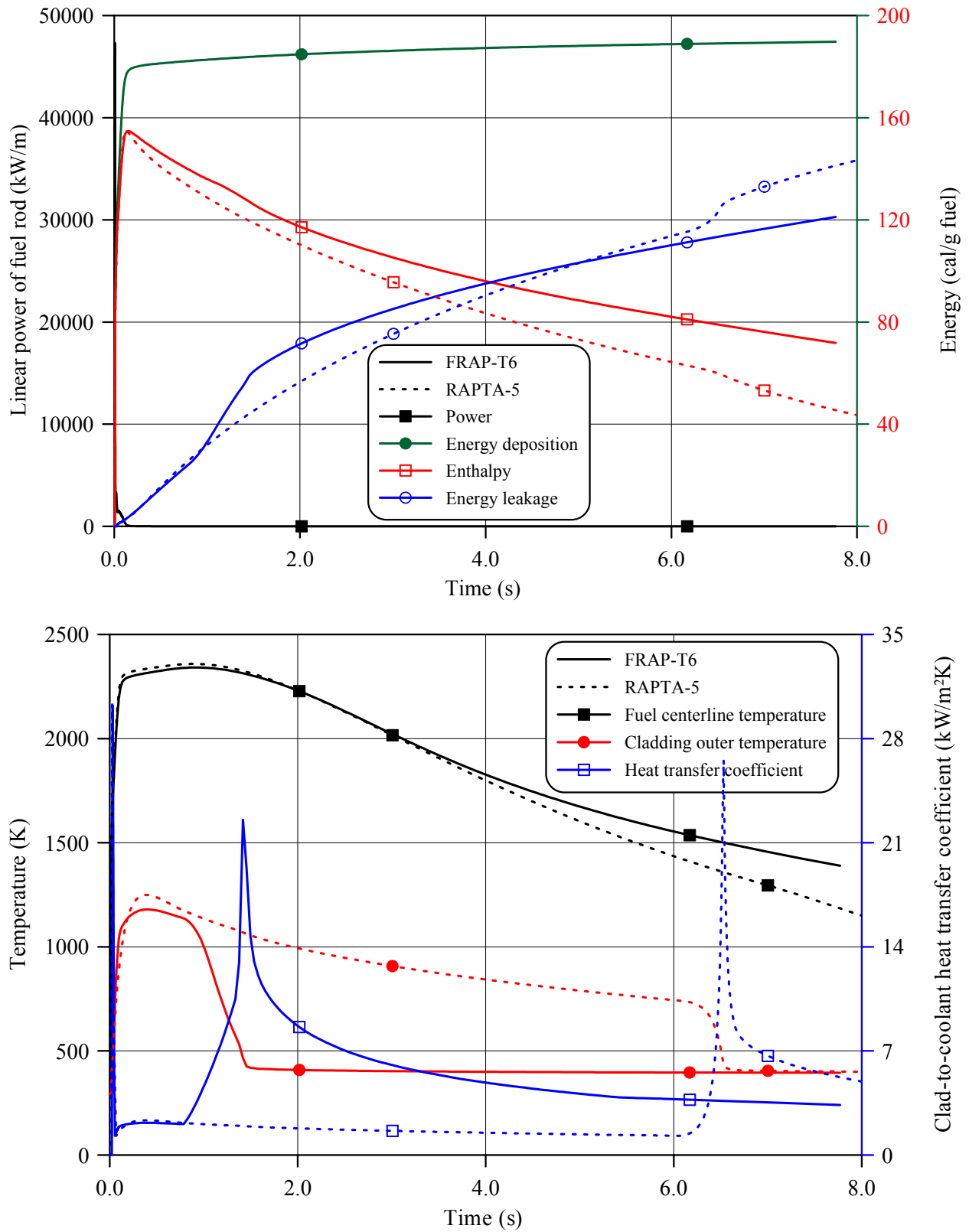
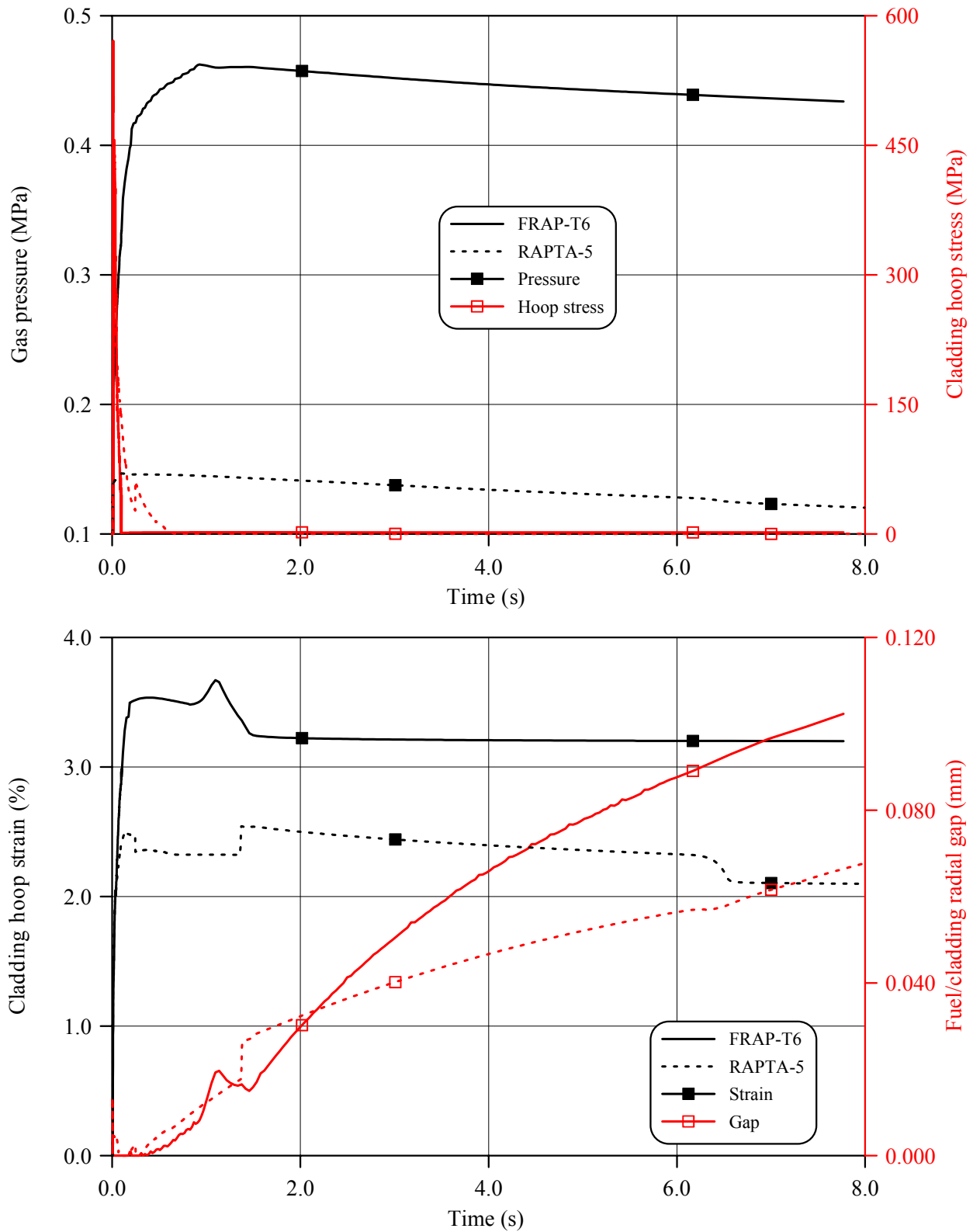


Fig.E-12.6. Thermal history of fuel rod # RT12 during the B1GR test in accordance with FRAP-T6/VVER and RAPTA-5 calculations

# # RT12



**Fig.E-12.7. Mechanical behavior of fuel rod # RT12 during the B1GR test in accordance with FRAP-T6/VVER and RAPTA-5 calculations**

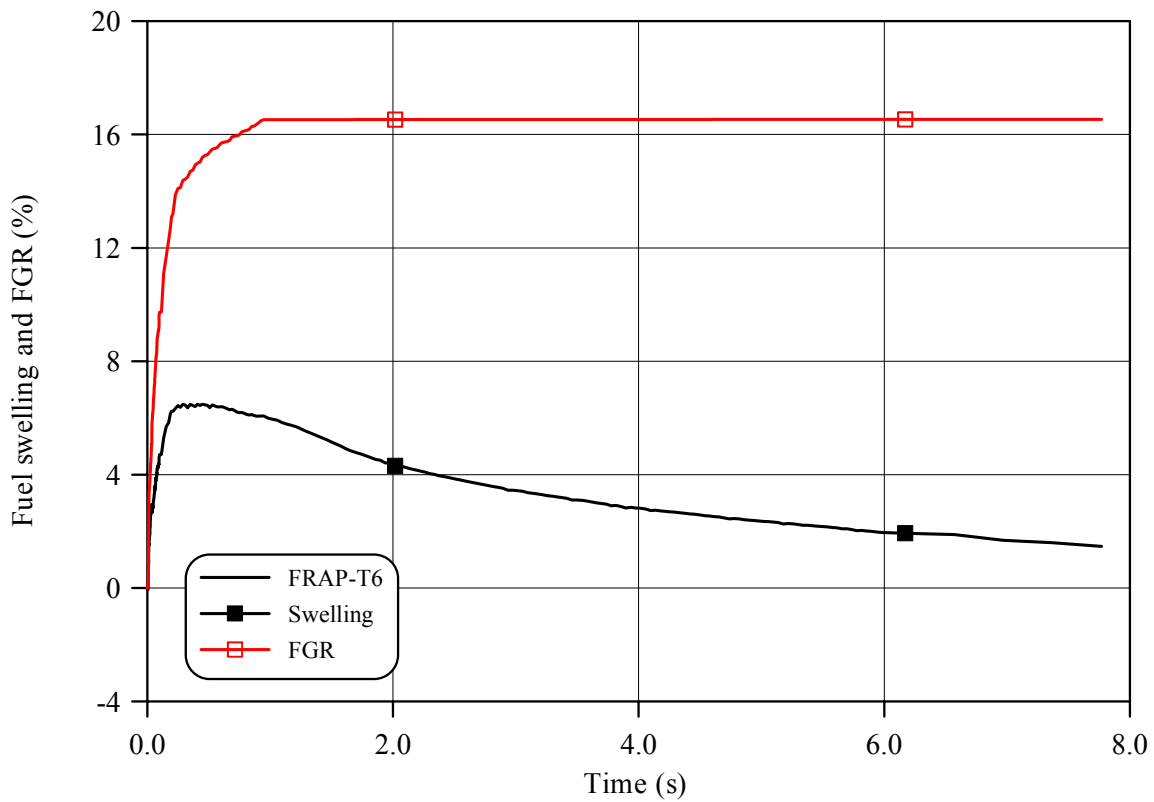
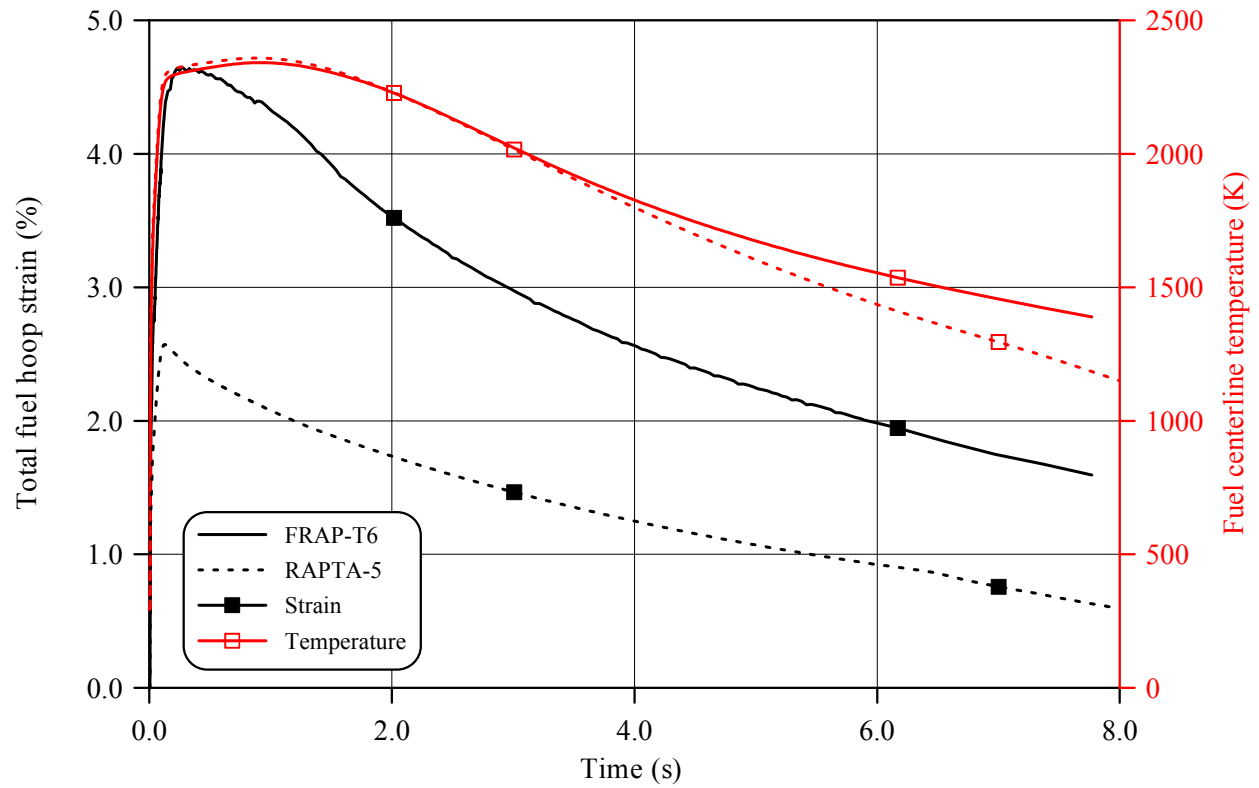


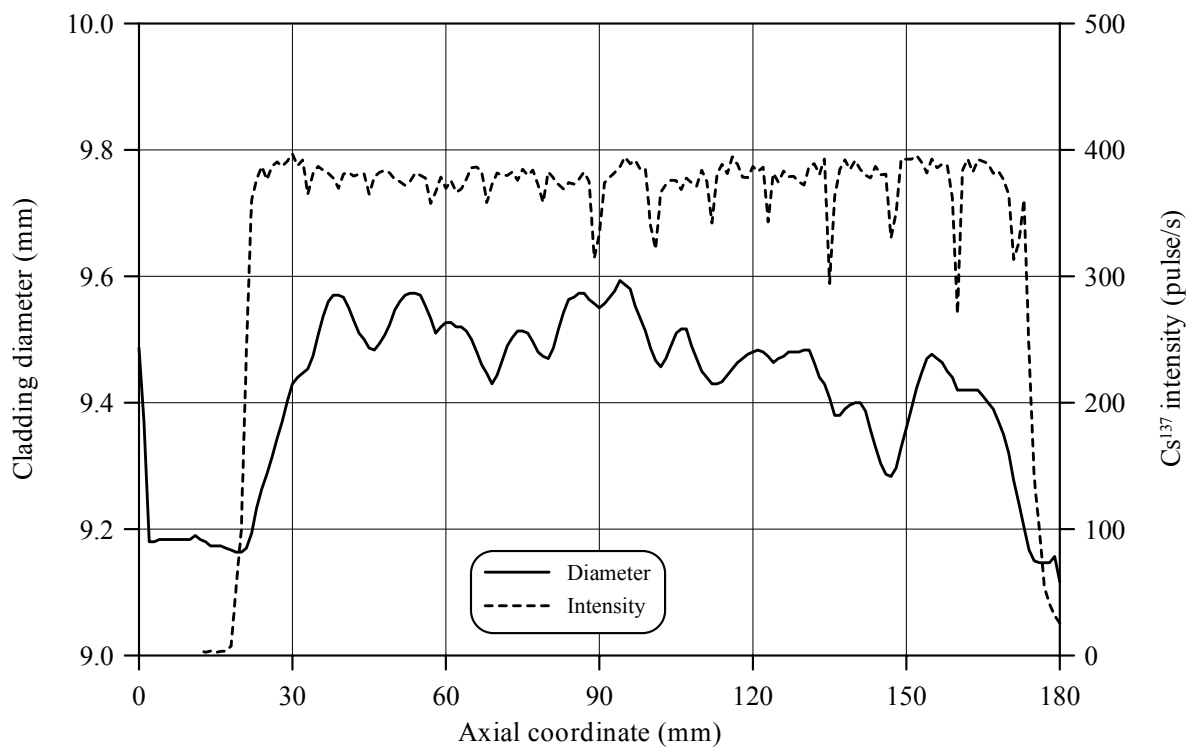
Fig.E-12.8. Fuel behavior during the BIGH test of fuel rod # RT12 in accordance with FRAP-T6/VVER and RAPTA-5 calculations

# # RT12

**Table E-12.3. Axial distribution of cladding average outer diameter in fuel rod # RT12\***

Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)	Axial coordinate (mm)	Cladding diameter (mm)
24	9.263	62	9.520	100	9.487	138	9.390
26	9.313	64	9.513	102	9.457	140	9.400
28	9.370	66	9.480	104	9.490	142	9.387
30	9.430	68	9.447	106	9.517	144	9.330
32	9.447	70	9.443	108	9.490	146	9.287
34	9.473	72	9.490	110	9.450	148	9.297
36	9.537	74	9.513	112	9.430	150	9.360
38	9.570	76	9.510	114	9.433	152	9.423
40	9.567	78	9.480	116	9.453	154	9.470
42	9.530	80	9.470	118	9.470	156	9.470
44	9.500	82	9.517	120	9.480	158	9.450
46	9.483	84	9.563	122	9.480	160	9.420
48	9.507	86	9.573	124	9.463	162	9.420
50	9.547	88	9.563	126	9.473	164	9.420
52	9.570	90	9.550	128	9.480	166	9.400
54	9.573	92	9.567	130	9.483	168	9.370
56	9.553	94	9.593	132	9.463	170	9.320
58	9.510	96	9.580	134	9.430	172	9.240
60	9.527	98	9.533	136	9.380	174	9.167

\* Measured value determined on the basis of profilometry data (16 azimuthal directions)



**Fig.E-12.9. Cladding measured average diameter and  $\gamma$ -scanning results for fuel rod # RT12**

Table E-12.4. The PIE results for fuel rod # RT12

Parameter		Value
1.	Cladding outer diameter (mm):	
1.1.	Maximum diameter of the bidimensional data sample in "fuel rod length - azimuthal angle" coordinates (mm)	9.60
1.2.	Averaged azimuthal diameter and maximum diameter along the length selected from the sample of averaged azimuthal diameter (mm)	9.59
1.3.	Averaged diameter of the bidimensional data sample in "fuel rod length - azimuthal angle" coordinates (mm)	9.46
2.	Cladding maximum residual hoop strain (%)	5.78
3.	Fuel pellet conditional diameter (mm) in cross-section*: at 54 mm elevation	8.05
4.	ZrO <sub>2</sub> outer thickness (μm) in cross-section: at 54 mm elevation	3–5
5.	ZrO <sub>2</sub> inner thickness (μm) in cross-section: at 54 mm elevation	0
6.	Parameters characterizing FGR:	
6.1.	Gas composition (% by volume):	
	He	35.13
	N <sub>2</sub>	0.58
	O <sub>2</sub>	0.08
	Ar	0.030
	CO <sub>2</sub>	0.100
	Kr	5.78
	Xe	58.30
6.2.	Free gas volume (cm <sup>3</sup> )	6.6
6.3.	Gas volume under normal conditions (cm <sup>3</sup> )	32.7
6.4.	Gas pressure under normal conditions (MPa)	0.50
6.5.	FGR (%)	22.70

\* Reference value determined by the processing of fuel cross-section photographs

# # RT12

**Table E-12.5. Organized BGR test results for fuel rod # RT12**

	Parameter	Unit	Value		
			Measured	Calculated	
				FRAP-T6	RAPTA-5
1.	Fuel burnup	MW d/kg U	47.4	47.4	47.4
2.	Initial gas pressure	MPa	0.1	0.1	0.1
3.	Energy deposition	cal/g fuel	198.1	198.1	198.1
4.	Peak fuel enthalpy*	cal/g fuel	-	154.7	154.9
5.	Fuel maximum temperature	K	-	2472	2466
6.	Maximum temperature of cladding outer surface	K	-	1180	1249
7.	Cladding burst	Failed, Unfailed	Unfailed	-**	-**
8.	Cladding residual hoop strain				
	- average***	%	4.35	3.11	2.54
	- maximum	%	5.78	3.11	2.54

\* Average value of peak fuel enthalpy 154.8 cal/g fuel

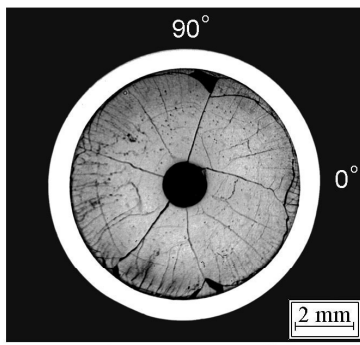
\*\* This parameter was not calculated

\*\*\* Average value along the fuel stack length

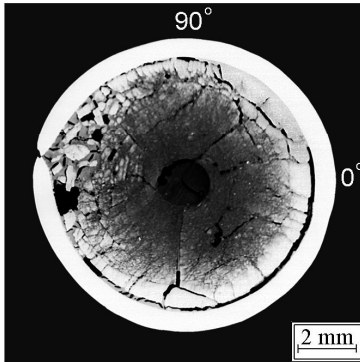
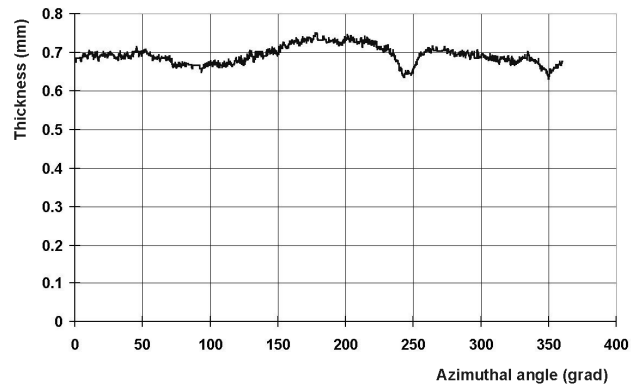
***Appendix E–13***

***Azimuthal Distribution of Cladding Thickness for Fuel Rods***

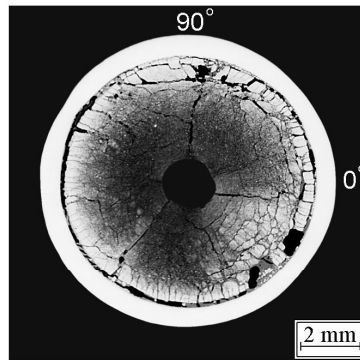
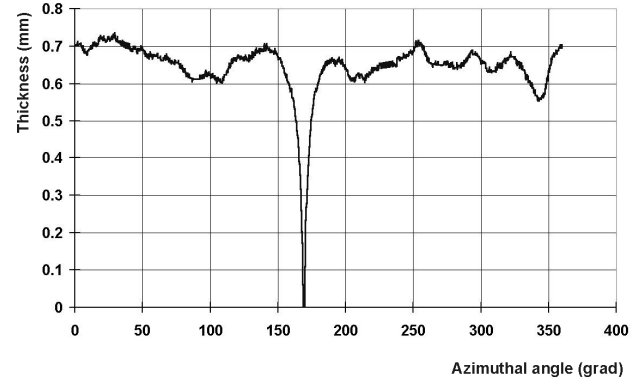
***## RT7–12***



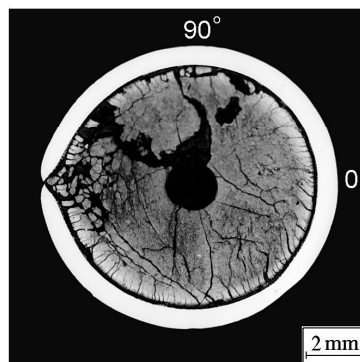
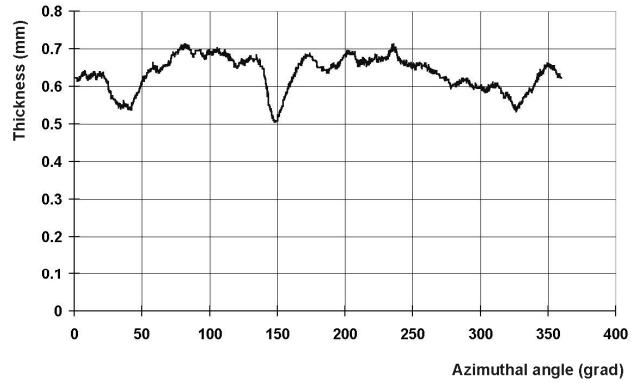
#RT7, elevation 107 mm



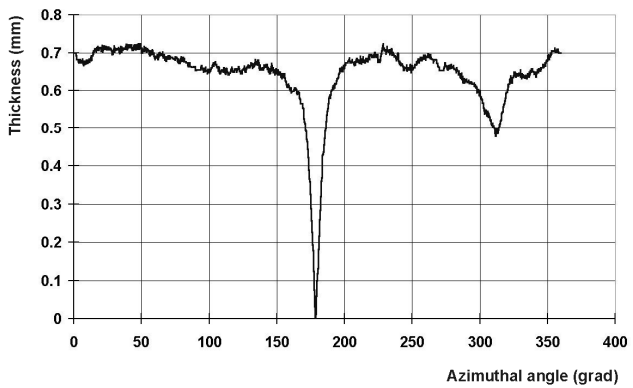
#RT8, elevation 53 mm



#RT8, elevation 97 mm

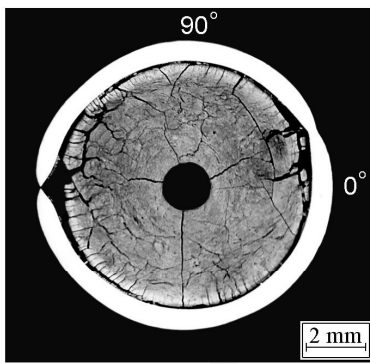


#RT8, elevation 133 mm

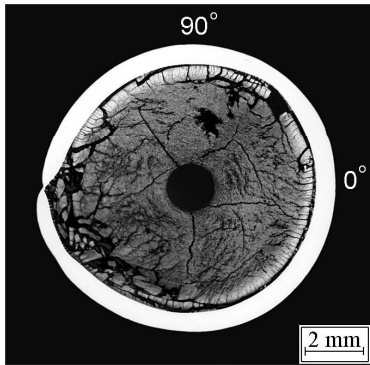
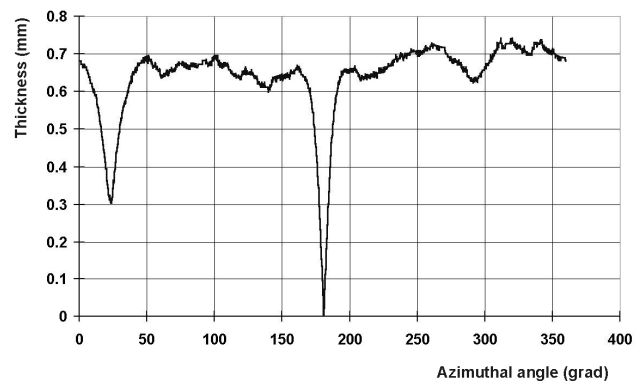


**Fig.E-13.1. Cross-section and azimuthal distribution of cladding thickness in fuel rods ## RT7, 8 after the BGR tests**

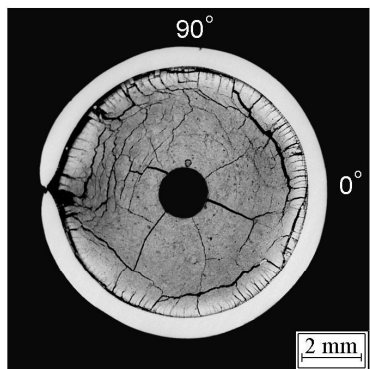
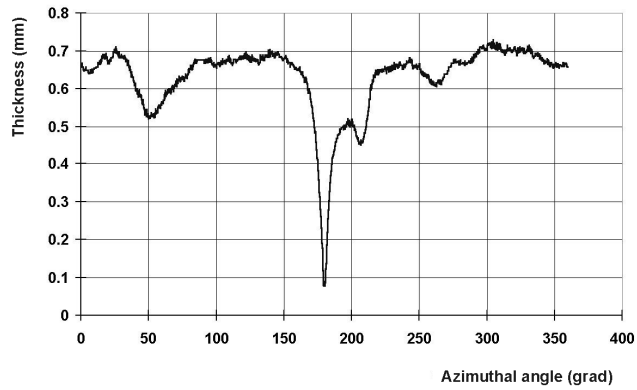




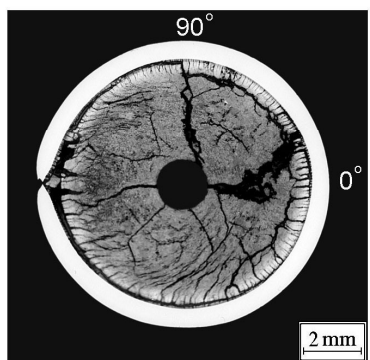
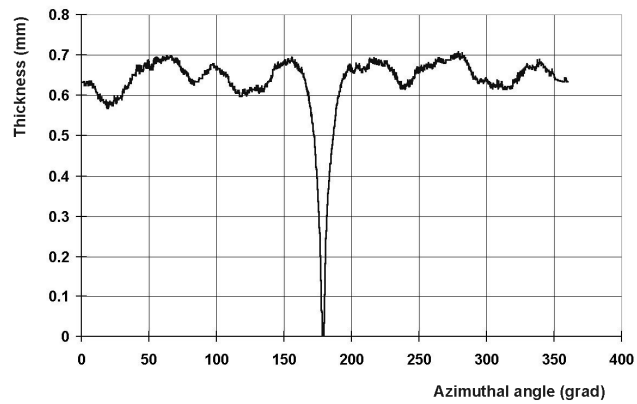
elevation 69 mm



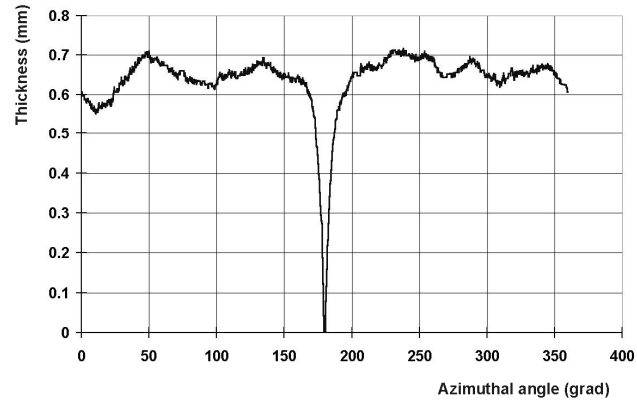
elevation 88 mm



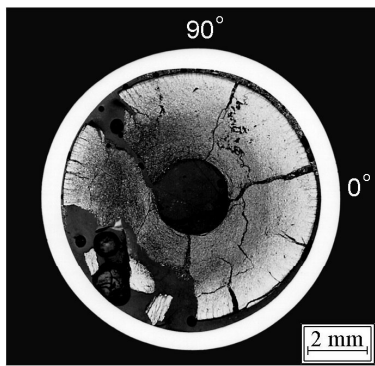
elevation 110 mm



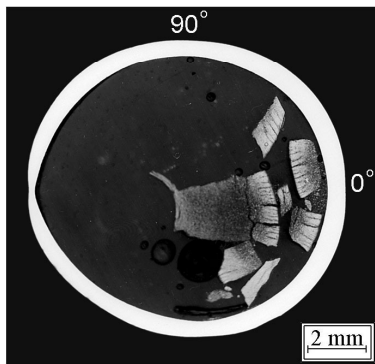
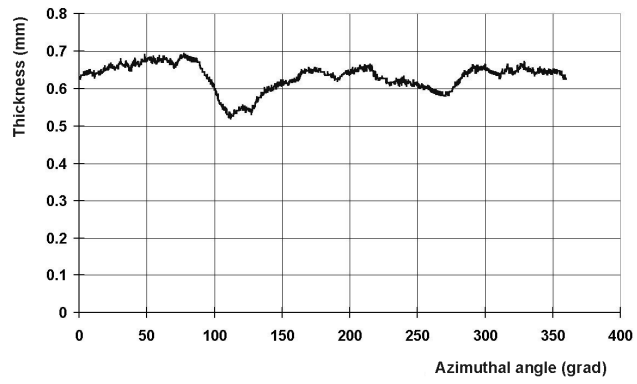
elevation 144 mm



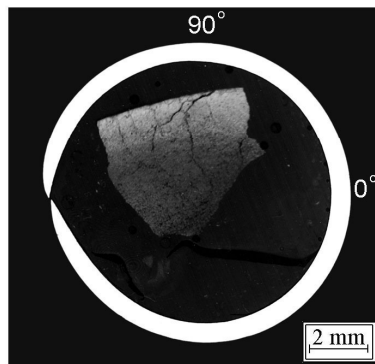
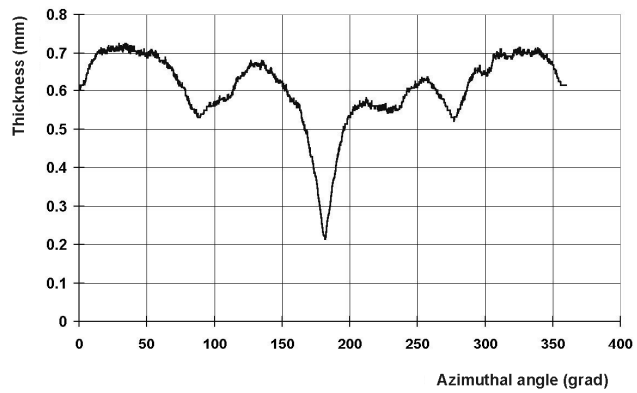
**Fig.E-13.2. Cross-section and azimuthal distribution of cladding thickness in fuel rod # RT9 for different elevations after the BGR tests**



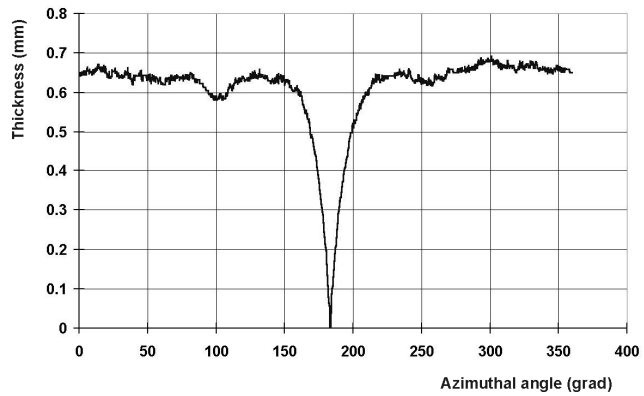
elevation 33 mm



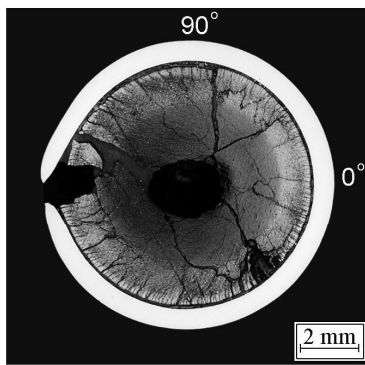
elevation 45 mm



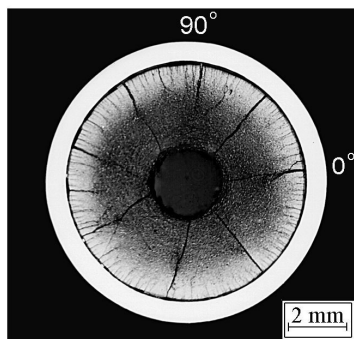
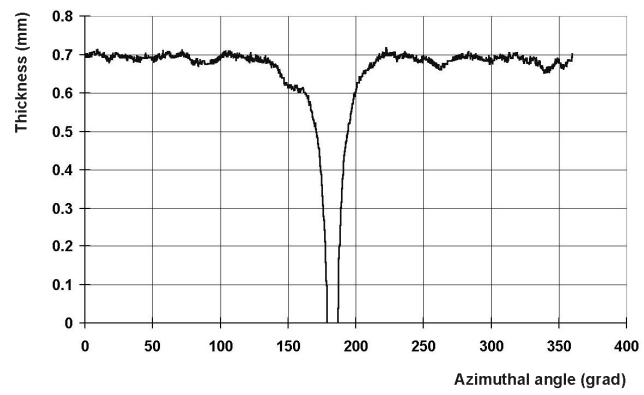
elevation 60 mm



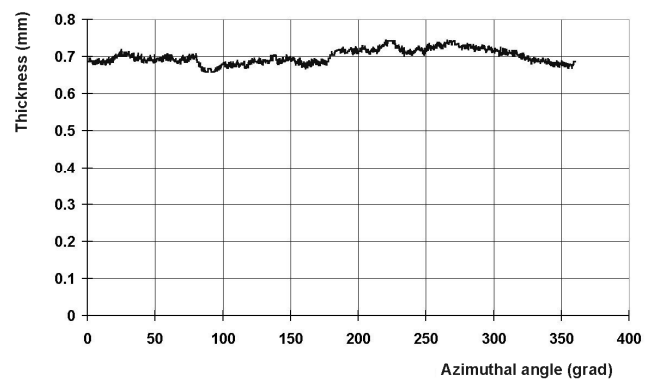
**Fig.E-13.3. Cross-section and azimuthal distribution of cladding thickness in fuel rod # RT10 for different elevations after the B1GR tests**



#RT11, elevation 157 mm



#RT12, elevation 54 mm



**Fig.E-13.4. Cross-section and azimuthal distribution of cladding thickness in fuel rods ## RT11, 12 after the BGR tests**



<b>NRC FORM 335</b> (9-2004) NRCMD 3.7		<b>U.S. NUCLEAR REGULATORY COMMISSION</b>		<b>1. REPORT NUMBER</b> (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)  NUREG/IA-0213, Vol. 2 IRSN/DPAM 2005-275 NSI RRC KI3230	
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